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Contents

Editorial: Nutrition, Immunity and COVID-19 <i>Hamid Jan B. Jan Mohamed & Tee E Siong</i>	i
Malaysian Food Barometer (MFB): a study of the impact of compressed modernisation on food habits <i>Jean-Pierre Poulain, Cyrille Laporte, Laurence Tibère, Elise Mognard, Neethianhantan Ari Ragavan, Anis Ashraf Zadeh & Ismail Mohd Noor</i>	1
Understanding barriers towards the use of food labels among Saudi female college students <i>Al-Barqi R, Al-Salem Y, Mahrous L, Abu Abat E, Al-Quraishi R & Benajiba N</i>	19
The role of public health dietary messages and guidelines in tackling overweight and obesity issues <i>Yi Yi Lee, David Tan, José Siri, Barry Newell, Yi Gong, Katrina Proust & Terry Marsden</i>	31
Development of a new questionnaire to assess childcare providers' KAP regarding infant and young child feeding <i>Najihah Mahfuzah Zakria, Tengku Alina Tengku Ismail, Wan Nor Arifin Wan Mansor, Zaharah Sulaiman & Tengku Fatimatul Tengku Hassim</i>	51
Determination of glycaemic response of a novel cane sugar product incorporated with <i>Phyllanthus emblica</i> and <i>Zingiber officinale</i> extracts <i>Chathuranga Hasithi Samarasinghe, Madhura Arunoda Jayasinghe, Senadheera Pathirannehelage Anuruddhika Subhashinie Senadheera, Isuru Wijesekara, Binosh Fernando, Kamburawala Kankanamge Don Somathilaka Ranaweera & Nirodha Heshan Bandara Wilamune</i>	65
Effect of <i>Morus alba</i> (white mulberry) leaf on HbA1c of patients with type II diabetes mellitus <i>Zoha Sohail, Nighat Bhatti, Saima Naz, Amna Iram & Saghir Ahmad Jafri</i>	77
Identification of dietary diversity associated with stunting in Indonesia <i>Laksmi Trisasmita, Trini Sudiarti, Ratu Ayu Dewi Sartika & Asih Setiarini</i>	85
Nutritional composition of indigenous durian varieties <i>Parunya Thiyajai, Somsri Charoenkiatkul, Kasem Kulpradit, Sasivimon Swangpol, Piyanut Sridonpai & Kunchit Judprasong</i>	93

Mango seed kernel flour (<i>Mangifera indica</i>): nutrient composition and potential as food <i>Fajriyati Mas'ud, Akhmad Rifai & Muhammad Sayuti</i>	101
Association between adiposity indicators and cardiorespiratory fitness among rural northeastern Thai adolescents <i>Weerachat Srichan, Tippawan Pongcharoen, Kunchit Judprasong, Pattanee Winichagoon, Sueppong Gowachirapant & Wanphen Wimonpeerapattana</i>	107
Microwave cooking enhances glycaemic potential of rice: An <i>in vitro</i> study <i>Bhupinder Kaur, Joseph Lim, Charoonsri Chusak & Christiani Jeyakumar Henry</i>	117
Vitamin D status is associated with high BMI, working status and gravidity among pregnant Malaysian women <i>Lalitha Palaniveloo, Yong Heng Yaw, Zalilah Mohd Shariff, Loh Su Peng, Jacques Bindels, Yvonne Yee Siang Tee & Eline M. van der Beek</i>	129

Editorial

Nutrition, Immunity and COVID-19

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The latest national and global health crisis is the ongoing pandemic of the infectious respiratory disease that was named as Coronavirus disease (COVID-19) in December 2019 (WHO, 2019). At the time of this article preparation almost 3 million cases and over 202,000 death have been reported worldwide (WHO, 2020). These numbers are dramatically increasing day by day. In Malaysia, up until 28 April 2020 a total of 5820 cases and 99 death were recorded (WHO, 2020).

COVID-19, caused by the coronavirus, is primarily spread during close contact such as touching and by fluid droplets produced through cough, sneeze or talk. Once the virus enters human body, it penetrates the cell of lungs, arteries, heart, kidney and intestines via the angiotensin converting enzyme 2 receptors, or ACE2 receptors (Hoffmann *et al.*, 2020). Inside the cells, it takes control of the cell's genetic reproduction process, replicates itself, and burst through the cell membrane. The severity of this infection may vary depending on the host's age, health condition and immune status. During an outbreak, good nutrition and a healthy lifestyle is extremely important.

This editorial serves to highlight: (a) the importance of public health nutritionists to play our part to promote healthy eating among the population to prevent or reduce the severity of the disease; (b) highlight the importance of research on nutrition and immunity which is not extensively explored in Malaysia.

This pandemic has emphasised that good nutrition and a healthy life is the key to strengthening immunity. This is particular important for the vulnerable group, including the elderly and people with underlying medical problems. Having a healthy bodyweight and consuming balanced diet (with particular focus on variety of fruits and vegetables) are important elements for supporting immune system that may help limit the severity of illnesses in those infected. Eating according to the Malaysian Dietary Guidelines as recommended by the Ministry of Health Malaysia ensures the intake of adequate amounts of energy, protein, micronutrients and other food components is the key to developing good immune system. Various dietary factors have gained particular attention. These include some vitamins and minerals (especially vitamin D, A and C, and zinc and iron), phytonutrients (bioactive compounds with antioxidant activities), and factors that promote gut health (including dietary fibre, adequate water and probiotics).

As a public education initiative, the Nutrition Society of Malaysia and Nutrition Month Malaysia (<http://nutriweb.org.my/index.php> and <https://www.nutritionmonthmalaysia.org.my>) have developed posters and media articles to emphasise to the population the importance of practising healthy eating and healthy lifestyle to fight COVID-19 while they are confined to the homes during the Movement Control Order (MCO). Notably several agencies and individuals utilise the social media

extensively in promoting health eating. Nutritionists should alert the public about dubious miracle cures. There are also researchers who conduct online surveys on investigating the effect of MCO on dietary intake, health behaviour and physical activities. Such initiatives are important, and findings should be shared with multiple stakeholders soon for further action as it does not seem likely that Malaysians, and indeed the whole world, will return to normal life any time soon.

COVID-19 pandemic had taught us some important lessons in many aspects of life that we have taken for granted, including nutrition and health. It is a wakeup call for Malaysians to pay more attention to healthy eating to maintain a healthy immune system. Indeed it is a timely reminder that good nutrition is the key to good health and prevention of diet-related diseases. It is imperative that the authorities pay serious attention to ensuring food and nutrition security for the population. The COVID-19 pandemic also reminds us that research on nutrition and immunity is still lacking in the country and it should be explored further with the support of multiple stakeholders.

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Malaysian Food Barometer (MFB): a study of the impact of compressed modernisation on food habits

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ABSTRACT

Introduction: The Malaysian society is undergoing rapid modernisation. The emerging middle class in Malaysia is influencing the lifestyles and traditional food habits of the main three ethnics (i.e. Malays, Chinese, and Indians). This article studied the impact of compressed modernisation on food in a multicultural context. The Malaysian Food Barometer (MFB), published in the year 2014, focuses on the socio-cultural determinants of food habits in Malaysia. **Methods:** The methods applied in the study were qualitative and quantitative surveys of the food barometers developed at the national level to study the transformation of eating habits. The surveys studied the socio-economic, demographic, and cultural determinants of food consumption, as well as identifying their possible influences on health issues. **Results:** The results showed two major distinguishing characteristics of Malaysian food patterns, i.e. linking with Malaysia's multi-ethnicity background and the high frequency of foods consumed outside of home by the urban population. **Conclusion:** The article concluded that like many societies in transition, Malaysia has to face a rise in the prevalence of overweight. However, with its multicultural characteristics, it becomes a privileged empirical field of observation for the analysis of modernisation modalities of diet models among different ethnic groups.

Keywords: Compressed modernity, eating out, social norms, meal, food cultures, food studies

INTRODUCTION

The Malaysian society is facing a rapid modernisation. From 1970, when the middle class started emerging (Shamsul, 1999; Embong, 2002; Embong, 2007), the traditional ways of life of the different national ethnic communities started changing. Malaysia has passed from under-nutrition to over-nutrition, and has experienced a transition from

mortality rates based on epidemic diseases, whose severity was reinforced by the lack of food, to a higher incidence of mortality through non-transmissible diseases and obesity. According to Shamsul (2012), "What a contrast between the student demonstration over the plight of peasants in Baling suffering from 'hunger and poverty' in 1974, and the establishment twenty years after of

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the Malaysian Association of the Study of Obesity (MASO), concern over the increase of obesity and other related non-communicable diseases (NCDs) medical problems”.

Furthermore, nutritional surveys have been scrutinising these transformations for many years. Tee (1980, 1994) published an annotated comprehensive bibliography of nutritional research from 1900 to 1993. After 1993, research on nutrition in Malaysia intensified (Tee, 1999; Ismail, 2002) and culminated with the Malaysian Adult Nutrition survey (MANS) in 2003, which was based on a national representative sample (MOH Malaysia, 2008a; MOH Malaysia, 2008b). The scientific production of nutritional studies on specific populations continued at a steady level among women (Karupaiah *et al.*, 2012), minorities in Peninsular Malaysia (Khor & Zalilah, 2008; Gan *et al.*, 2011), as well as in Sabah and Sarawak (Py *et al.*, 2012). A new Global Nutrition Survey has been launched by the Ministry of Health (MOH) Malaysia. All these research projects focus mainly on the food intake of individuals, evaluated in terms of nutrient composition (macro- and micro-nutrients), with some ethnic dimensions included.

Simultaneously, one could find a body of ethnographic and anthropological literature on the food habits, beliefs, and taboos relating to the Malaysian indigenous *Orang Asli* population (i.e. originally mountainous jungle dwelling hunter-gatherers, mainly the Senoi and Negrito groups) (Bolton, 1972; Lim & Chee, 1998), besides specific times in their life cycle such as pregnancy and confinement (Manderson, 1981). Previous studies on nutrition have already paved the way in this direction (Ismail, 2002; Rampal *et al.*, 2007; MOH Malaysia, 2008b). Adaptation of food pyramids to local cultures has been undertaken, however, the impact is largely unknown

and needs to be evaluated. Nevertheless, a survey which focuses on the socio-cultural determinants of food habits at the national level has been missed. Therefore, the aim of the Malaysian Food Barometer (MFB) is to fill this gap. MFB studies the social, ethnic, and cultural diversification of food habits in Malaysia. It also investigates the evolution of food consumption, both at home and outside the home, and identifies the consequences in terms of market factors and public health.

In addition, this study is based on the empirical data from a research conducted in 2012 - 2014 as part of the ‘Food Studies Chair: Food, Cultures and Health’ in collaboration with Taylor’s University (Malaysia) and the University of Toulouse Jean Jaurès (France). In this article, after discussion about the effects of modernisation on the Malaysian society, we present the methodology used and the objectives of the MFB. Next, we expose some of the results relating to two main characteristics of the Malaysian food model. Finally, we discuss about how the theory of ‘compressed modernisation’ explains the Malaysian situation.

Understanding the effects of modernisation in a multicultural context

The main objective here is to analyse the effects of the very fast modernisation (what is called “compressed modernisation”) on food cultures and practices of different Malaysian ethnic groups. The process of modernisation in Malaysia is characterised by rapid urbanisation and rural exodus. The urban population increased from 11% in 1951 to 51% in 1991, and from 62% in 2000 to 73% in 2012 (Jaafar, 2004; BMCE trade, 2013), which was accompanied by the industrialisation of the New Economic Policy Era in 1971-1990 (Aziz, 2012) and the development

of the services economy from 1970 (Hutton, 2003).

Furthermore, at stage three of the demographic transition model (DTM), which is characterised by a drop in birth rate, the structure of the Malaysian society is changing. The fertility rate decreased from 3.29 children per woman in 2000 to 2.64 in 2012 (Index Mundi Malaysia, 2013), and the size of household being reduced from the average 5.2 persons in 1980 to 4.3 in 2010 (Sudha, 1997; Mahari *et al.*, 2011). The increase in purchasing power of newly waged and salaried employees is an additional factor that is combined with the reduction in family size to herald the emergence of a new middle class (Shamsul, 1999; Embong, 2007), as well as a new working class with greater ability to participate in the consumption economy.

Moreover, related epidemiological transition has modified the causes of mortality from epidemic diseases to cardiovascular diseases, cancers, and degenerative diseases. The success of modern medicine in understanding and taming these diseases points out that lifestyles and food habits are levers, both for prevention and for care. The life expectancy has gained 3.2 years in 12 years between 2000 and 2012 (Ismail, 2002; Index Mundi Malaysia, 2013). Therefore, the current obesity epidemic in Malaysia and worldwide raise concerns about the negative effects of such transformations, and stimulate us to focus research on identifying those factors in the food cultures and lifestyles leading to the development of this issue. All these macro structural developments have affected the lifestyles and the food habits of various ethnic groups which make up the Malaysian population. Hence, we can speak about a stage of food modernity in Malaysia which can be regarded as a consequence of the modernisation of the Malaysian society.

This stage is characterised by the transformation of food intake patterns besides the new consumer expectations and aspirations in relation to food.

In addition, most of the above characteristics can also be found in modern countries. Nevertheless, the Malaysian food consumption context has two major distinct characteristics.

The first characteristic is linked with Malaysia's multi-ethnicity background and the Malaysian society, which consists of four groups. However, the Malaysian society is much more complex than the official organisation of these four main groups and three main ethnic groups (i.e. Malay, Chinese, and Indian, besides a few minorities). As a matter of fact, each group has its own food culture with its typical dishes and ingredients, dietary taboos and restrictions, dining rituals, form and structure of meals, and symbolic 'racial' dimensions of food, which are not totally homogenous in Malaysia. However, 'racial' categories are not homogeneous in Malaysia. For example, Indians may belong to different religions. They may be Hindus, Muslims, Sikhs, Buddhists, Christians, or members of the New Religious Movements. They may speak in *Bahasa Malaysia* as the national language of Malaysia, English, and different mother tongues (e.g. Tamil, Hindi, Urdu, and Malayalam). They may also be identified strongly by a Caste (different regions of India) or by the neighbouring countries of India where they come from such as Pakistan and Sri Lanka, and also by their families, who may have lived in Malaysia for several generations or just arrived. In addition, 'Chinese' may be Buddhist, Taoist, Christian, or Muslim converts. They may speak Hakka, Hokkien, Cantonese, Teochew, and Mandarin. They may also be Min people, Hakka, Cantonese, and Wu. Furthermore, there are Malaysians in the official 'others' category such

as the non-Malay Bumiputra, Dusun, Iban, and Kadazan. We have to add foreigners living in Malaysia to this heterogeneous group, including expats (executives and domestic aids), tourists, and international retirees on the 'second home' programme (Tan & Ho, 2014).

Furthermore, the boundaries between these three main ethnic groups (or races, which is officially used) are not very hermetic. These groups have a certain 'porosity' resulting from interpersonal relationships across ethnic boundaries through friendship, overlapping of religious affiliation and language competence. This 'porosity' is also resulted from the usage behind the primary 'race' identity, religious conversion, and 'crossbreeding' (multi-ethnic people) from historical institutionalised mixed marriages (e.g. in the Baba-Nyonya community in historic times). In addition, it can also be a result from an actual inter-racial breeding, with or without conversion (Hirschman, 1975; Hirschman, 1987; Clammer, 1980; Tan, 1982), and the rise of individualism within, which Malaysians develop personal preferences in choosing from a wide variety of dietary alternatives. Moreover, there are some 'crossbreeding' among the different food cultures. For example, Nyonya cuisine from the Malacca region is a combination of Chinese and Malay food cultures with some influence from the Portuguese. Some restaurants such as Mamak restaurants, which are originally from Tamil Muslims, are now filled up by consumers of all ethnic groups and make a solid contribution to the development of a 'Malaysian mixed' food culture - that is, some dishes and food practices that are commonly shared by, or are compatible with more than one 'ethnic' groups.

The second characteristic is the high frequency of foods consumed outside of home by the urban population in

Malaysia, which is probably rated as one of the highest in the world (Fournier *et al.*, 2016). The population study (MOH Malaysia, 2008b) revealed a strong positive correlation between the high incidence of food consumed outside of home with the level of urbanisation. As urbanisation increase, the opportunities for Malaysians to eat out have increased tremendously and prices are sometimes lower than homemade meals. The idea that the growth of urbanisation develops a food environment with a higher density of outlets, as well as the consequences of increasing the prevalence of eating out and the outcomes of health is being documented in the Western countries (Obbagy, 2012). In this study, we do not mention that eating out could be globally linked with the rise of obesity. Rather, we assume that there is a typology based on a cluster of practices which structure the ethnic food lifestyles in Malaysia, and some of them are connected with obesity. In addition, the range of practical contexts in which Malaysians consumers are deciding what to eat are very different from those encountered in the West. Therefore, public health programmes developed in Europe and USA cannot be transferred to Malaysia without the risk of facing some socio-cultural resistance that consequently would have some counterproductive effects.

Therefore, in this context, MFB is a tool to identify and study in depth the socio-cultural determinants of Malaysian food habits. MFB describes the 'food social space' of the Malaysian population. It also focuses simultaneously on the practices and on the representations of food cultures. The aim of MFB is to understand the food lifestyles and the different food contexts of various Malaysian ethnic groups and 'middle class'. In addition, by using a follow-up survey in this study, we could investigate the longitudinal transformation of

food habits in Malaysia. Finally, these different sets of data and their analysis could be used to uncover the social infrastructure of Malaysians' eating decisions (i.e. patterns, scenarios, and contexts).

METHODOLOGY

Food barometers are tools developed under the direction of Jean Pierre Poulain and his team to study the socio-economic, demographic, and cultural determinants of food consumption. They also try to identify the possible influences of food consumption on health issues, particularly NCDs, where diet is involved. In addition, food barometers complement traditional nutritional surveys and aim to participate in the development of prevention programmes (Poulain 2001; Poulain *et al.*, 2010; Poulain *et al.*, 2015; Fournier *et al.*, 2016). They are also qualitative and quantitative surveys developed at the national level to study the transformation of eating habits.

MFB uses a mixed-mode approach, both qualitative and quantitative methods. The questionnaire developed from the outcomes of a qualitative exploratory phase (face-to-face interviews and a focus group) aims to identify the main trends in Malaysian food practices and representations. The questionnaire is organised into six parts: the socio-demographics and ethnic indicators, food norms, diet recall of the last 24 hours, cooking practices, social representations regarding food, and the perception of food and health-related risks. The questionnaire comprises of 66 items with more than 1400 variables including body mass index (BMI). There are 46 closed and multiple-choice questions, consisting of standard questions used in sociology to describe the socio-demographics of a population, as well as questions that have been used in previous food studies (Poulain, 2002;

Poulain *et al.*, 2010) but adapted to the Malaysian context. The questionnaire was translated into three languages (Malay, Chinese, and English) and then retro-translated. All interviewers (n=42) employed for administering the questionnaire were fluent in English, in addition to at least one (other) language to which the questionnaires had been translated. Six interviewers were trained for two days. The purpose of this was to present the structure of the questionnaire and to validate the data collection method. The sample size was 2000 participants of ≥ 15 years old, estimated using power calculation (Ali & Azlan Abdullah, 2012; Fournier *et al.*, 2016). The sampling methodology was of a semi-randomised approach based on the regions within Malaysia and their degree of urbanisation. A quota system based on age and ethnicity was also applied. Quantitative data were collected from January to May 2013.

Furthermore, MFB studies eating habits through the socio-anthropological approach to establish an interdisciplinary dialogue with nutrition for public health benefit. The analysis of socio-cultural determinants of meal structures, days, and dietary patterns enriches the approach in terms of individual dominant decision-making in the field of nutrition and health (Fischler, 1990; Warde, 2005; Poulain, 2017).

Operational objectives

The purpose of the MFB is to draw a picture of the Malaysian food habits to study their diversity based on socio-cultural determinants. MFB describes the food habits and food cultures at different dimensions, such as practices, social norms, social representations, and beliefs. These dimensions analyse the effects of social status, level of education, ethnicity, gender, generation, and size of the household and urbanisation. It also measures the importance of eating out

and prevalence of using convenience food. MFB identifies the food lifestyles with a special focus on the role of ethnicity in the middle class. In addition, it studies the correlation between lifestyle, social characteristics, and body size (i.e. obese and overweight). These data facilitate a comparative analysis between different stages in Malaysia’s history and economic development, and between different countries as well.

Therefore, the operational objectives of MFB are to produce useful data for different categories of stakeholders. These stakeholders include: 1. The public health stakeholders (from epidemiologists to those engaged in health and nutrition education), 2. The economic stakeholders (including agro-

food chain stakeholders, restaurants, and foodservice industries), and 3. Academics, who work in the different disciplines and are interested in food consumption and food cultures from anthropology to sciences of nutrition. Figure 1 shows the general objectives of the MFB.

Scientific objectives

The main scientific objective of the MFB is to challenge the theories of ‘convergence’ (Mahbubani, 2013), which suggested that with economic development and the emergence of the middle class, food consumption patterns are less determined by socio-cultural factors (in Malaysia, ethnicity) than the consumption culture, which is

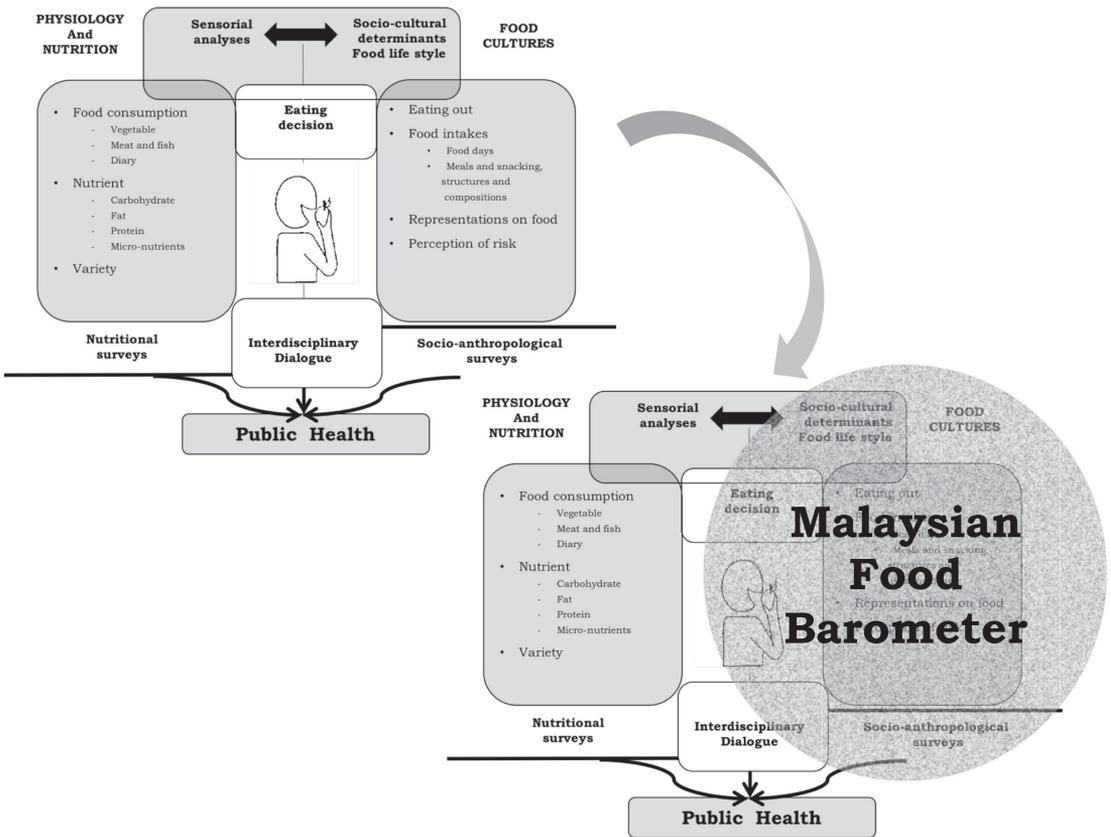


Figure 1. General objectives of the Malaysian Food Barometer (MFB)

the distinctive feature of middle class. The stage of convergence should be the homogenisation of middle-class lifestyles. Therefore, this study seeks to answer the question of ‘what is the significant role of ethnic factors within the middle-class conventions of food consumption?’. In addition, as said above, food habits are strongly determined by culture, religion, and social beliefs, therefore, a detailed empirical study seeking rich qualitative data is a meaningful exercise here.

Furthermore, the MFB focuses on food habits at two different levels, i.e. national level and international level. At the level of the Malaysian social and ethnic groups, the survey considers the following questions: 1. Is there a homogenisation of the Malaysian lifestyle across ethnicity and social positions? 2. What are the consequences of food consumption for frequenting restaurants, casual food stalls, and buying takeaway food? and 3. What is the connection between these practices and the development of obesity in Malaysia? At the international level, the survey considers: 1. Is there a convergence of food consumption models through the process of economic development (e.g. is there an increase in foods of animal origin in the daily diet)? 2. How can we describe and understand the concept of inertia in relation to food cultures? and the main question, 3. How can we understand and model a culture’s inertia in the transformation of food habits?

DISCUSSION AND CONCLUSION

Studying the importance of eating out in the Malaysian daily practices

Two types of data are available within the Malaysian context. The first type of data are produced by economists, and are interested in the locations where the act of purchase takes place (the central notion is the ‘food away from home’). The second type come from surveys and MFB,

and report on the food consumption act itself. In this case, we talk about ‘eating out’ as well. The two types of data are thus not equivalent. In the case of food, ‘economic consumption’ and ‘food consumption’ are disconnected in time, and most often are not individualised purchases for home food, while payment and consumption are simultaneous and individualised in the case of ‘out of home’ catering.

In addition, economists who work on household food budget distinguish the proportion of expenditure on foods consumed at home from foods consumed outside the home. The data mobilised by Lee & Tan (2007) showed that the share of household ‘food away from home’ expenditures increased significantly between 1973 (4.6%) and 1999 (10.9%). We have aggregated to their data more recent figures (2009; 2014) to develop the graph below. Even though these elements are not completely comparable, they do point to a continuous increase in out-of-home diet spending.

Figure 2 shows the expenses of food consumed at-home and outside of home (eating out) as a percentage of total household expenditure. Data for 1973 to 1999 were from Lee & Tan (2007), while data for 2009 and 2014 were from the Department of Statistics Malaysia (2016).

Furthermore, other works (Ali & Azlan Abdullah, 2012) centred on the issue of risks (social and health) and the practice of eating out without any nutritional regard, focused on the development of consumption out of home for specific audiences (e.g. students, families, and people in their work places) with observation in some areas of Malaysia such as Bandar Baru Bangi, Jitra and Segamat. This study (however, does not provide the explicit data) explains this movement by factors such as the lengthening of the distance between workplace and home, increase in the

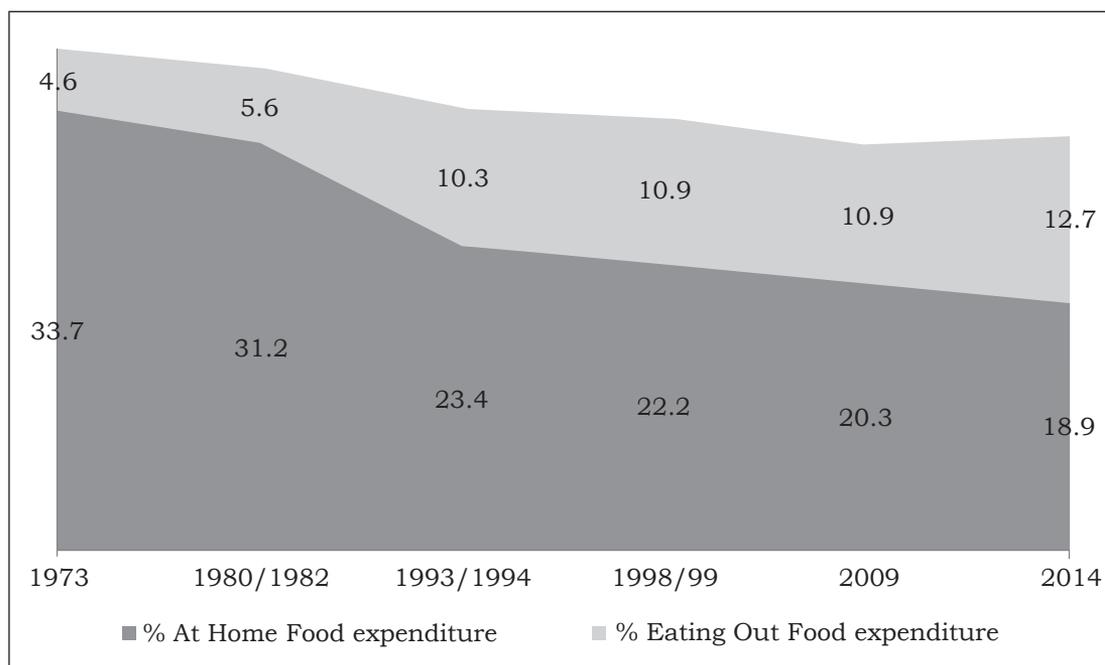


Figure 2. Expenses of food consumed at-home and outside home (eating-out) as a percentage of total household expenditure. Data 1973 to 1999 (Lee & Tan, 2007); data 2009 and 2014 (Department of Statistics Malaysia, 2014)

work of the ‘mothers’, and the profusion of food supply in catering. Restaurants not only provide ‘meal time’ foods, but also provide the opportunity to eat at any time in a variety of contexts (e.g. work meeting and celebration). While the purpose of these analyses is to show the risks (for health, social, and familial) of the development of ‘eating out’ in dietary practices, they also complete a first panorama that outlines the importance of ‘eating out’ in Malaysia.

Moreover, in MFB, we used two main indicators to study the ‘eating out’ practices:

1. Reconstruction of the food taken of the previous week: the value of the weekly intake is 1 when all food consumption is carried out, and the value is 0 when all intakes are consumed at home.
2. The 24-hour recall with: a ratio

of ‘out-of-home’ frequency based on food intake (i.e. the number of intakes out-of-home/total number of intakes) and a frequency ratio per individual (i.e. the number of individuals with at least one ‘out of home’ intake).

Two perspectives can be used to describe ‘eating out’: the proportion of meals consumed by the overall population, and the frequency of ‘eating out’ for individuals. Therefore, >38.3% of Malaysian meals (breakfast, lunch, dinner, and supper) are consumed outside of home (Table 1). And if the food consumed at home is added, but the dishes are from outside (meals delivered or purchased as take away, including from Mamak restaurants), the frequency rises to 47.5%. These practices are positively related to the level of urbanisation, i.e. 32.9% among

Table 1. Eating out – only meals (breakfast, lunch, dinner)

Type of data	Eating out practices for meals only			
	Meals		Individuals	
	n	%	n	%
Total Intakes	5,566	100.0	2,000	100.0
Eating at least one meal outside	2,134	38.3	1,282	64.1
Eating at least one meal at home	3,422	61.7	1,768	88.4
Eating at home but the meal comes from outside	515	9.2	455	22.7

rural people, compared to 39.7% for urban dwellers, and 40.2% for suburban residents (Poulain *et al.*, 2014).

At the individual frequency level, >64% of people consume at least one meal per day outside. From these data, we drew a food landscape in which the number of meals eaten outside the home, and imported meals eaten at home are at a relatively high level (22.7%) (Figure 3).

In addition, an investigation carried out by the MOH in 2008, associated these practices to the phenomena of urbanisation. The opportunities for Malaysians to go out of their homes

to eat have significantly increased as prices are sometimes lower than the costs of homemade meals. Taking into account the main socio-economic developments and the demographic evolution of the Malaysian society, we can predict an increase in ‘eating out’ practices. Consequently, the ‘industry’ of catering is a front-line player in the problem of increasing obesity and NCDs (Laporte, 2018). The contexts in which Malaysian consumers decide what to eat considerably differ from Westerners. Therefore, public health programmes, mainly centred on family diet, that

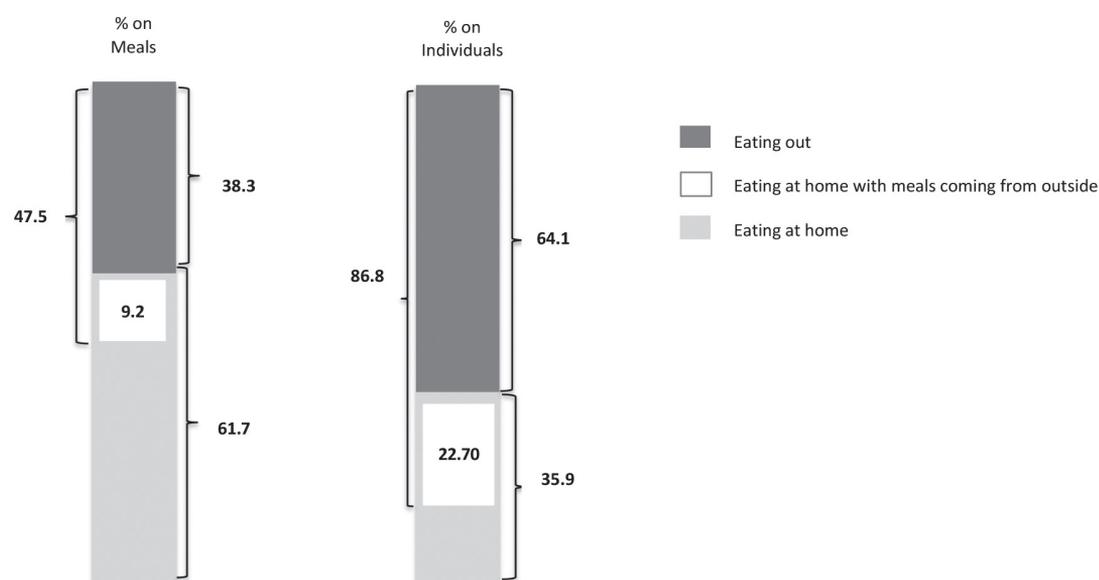


Figure 3. Eating out in Malaysia – percentage of eating out per meals and per individuals (Poulain *et al.*, 2014)

are implemented in Europe and the United States cannot be transposed to Malaysia without the probable risk of counterproductive effects.

Individualisation of dietary practices

Dietary modernity in Malaysia is characterised by an increasing individualisation of food practices noted on several levels, especially the structure of meals. Lévi-Strauss (1963) identified two forms of meal structures. The synchronic form that results in the service of several dishes simultaneously during the same meal, and the diachronic form that results in the service of several dishes, one after another, according to socially predefined rules. The contemporary French meal, which follows a sequence of order ‘starters - main dish - cheese - dessert’, is an example of a diachronic meal in spite of some variations over time and from one social group to another (Fischler, 1990; Poulain, 2002; Poulain, 2017). Some meals are also

organised around a main product, which is systematically presented, and is accompanied by other complementary products that may vary from one meal to another. The organisation of a Chinese meal follows the same principle. In other food models, like the French meal, the products are constantly changing. Finally, in the Malaysian society, the level of individualisation is more or less pronounced according to meals (Figure 4).

The process of individualisation is pronounced in ‘lunch’, where only 27% of individuals express individual structures and 74.9% have individualised lunch practices. This dissonance in high norm versus practice (47.9) reflects the individualisation movement. It is similar to dinner where only 18.3% of respondents express individual structures, whereas 66.2% of the population implements individualised practices. This strong dissonance between norms and practices (+47.9) points to an attachment to the collective



Figure 4. Structure of meals – norms vs. practices (Poulain et al., 2014)

model in norms coexisting with an individualisation of practices. This situation can be explained by the rapid modernisation of the Malaysian society. However, we observed that certain social groups, such as individuals who live in rural areas or groups like the non-Malay Bumiputras, are hermetic to individualisation, particularly for breakfast. This persistence is also found in individuals with low levels of education at the bottom of the social hierarchy.

The Malaysian food model is therefore characterised by a very high level of eating out and a rapid transformation that focuses on the individualisation of meal structures, mainly for lunch and dinner. This particular context can be relocated in the framework of what some sociologists call 'compressed modernisation' (Chang, 1999; Chang, 2016; Rouleau-Berger & Neng, 2017; Augustin-Jean & Poulain, 2018).

A 'compressed' modernisation in Malaysia

Malaysia is a good example of 'compressed modernisation'. We mentioned above that the middle class emerged during the new economic policy of industrialisation (1971-1990). The traditional lifestyles of different ethnic communities have changed profoundly. In a few decades, Malaysia has shifted from undernutrition to overnutrition, and is now confronted with what public health experts call 'the epidemiological transition' and the 'double burden' of malnutrition (Gillespie & Haddad, 2003). The first phenomenon is the transition in mortality rates, caused by epidemic diseases and reinforced by food shortage, to deaths from NCDs (e.g. cardiovascular diseases and cancer), in which obesity is a significant risk factor. The second phenomenon, the double burden, is the cohabitation of undernutrition and overnutrition problems within the same

population, and at the same time.

The speed of modernisation in some Asian countries has led Korean sociologist, Chang (1999) to propose the concept of 'compressed modernisation', which corresponds to a civilisational context in which economic, political, cultural, and social changes occur in an extremely condensed manner, both in space and time. Also, in which disparate historical and social elements coexist and contribute to the construction and reconstruction of a complex social system characterised by fluidity (Chang, 2016). The compression phenomenon of space and time was described in the mid-1980s by the geographer Harvey (1990). It would be the result of technological innovations developed in the sectors of communication (e.g. telegraph, telephone, fax, and internet), and transport and travel (e.g. high-speed train TGV, democratisation of air transport) which reduces, or sometimes cancels off distances and time. The technological innovations are at the heart of economic development, and help to open up new markets, displace space barriers, speed up production cycles, and reduce capital turnover.

In addition, in the work of Beck and Grand (2010), i.e. articulating theorisation in terms of compressed modernity (Chang, 1999) and the first and second modernity, the authors propose to define it as a situation in which the processes of urbanisation, industrialisation, and economic liberalisation are faster than the transition through a first modernity and the transition to a second modernity which are almost simultaneous. The first modernity corresponds to the rise in rationality and 'de-traditionalisation' of societies. The second one corresponds to a weakening of the legitimacy of 'normative devices', resulting in an 'individualisation of lifestyles' (Beck & Lau, 2005) and to the post-traditional societies, not in the sense that there is

no more intergenerational transmission, but in that the normative models have lost their strength and their evidence. The compressed modernity in some Asian countries corresponds to the telescoping of these two forms of modernity.

Furthermore, Chang (1999) describes two sub-phenomena that have an impact on temporal and spatial dimensions, i.e. 'condensation' and 'compression'. Condensation refers to the physical processes required for the movement and change between two moments (epochs), and between two locations (places) to be abridged or compacted. Compression, corresponds to a phenomenon according to which various components of multiple civilisations that existed in different zones and/or places coexist in the same delimited space-time and influence each other. Continuing the reflection on the topic of diet, Poulain (2018a, 2018b) showed that compressed modernity is characterised by the strengthening of the process of patrimonialisation of food cultures, the development of cosmopolitan food cultures, and the rise of some eating anxiety such as:

1. The patrimonialisation of cultural diets: the reduction of time intensifies the designation of 'traditional' food cultures as heritage, and as the central features of the construction and expression of ethnic and social identities. Patrimonialisation is a concept under construction that has opened several heuristic perspectives (Poulain, 2000; Geyzen, 2014; Brulotte & Di Giovine, 2016; Bessiere, 2018). In Malaysia, this phenomenon is seen with the increase in the number of chain restaurants in major shopping centres, such as Madam Kwan's, Little Penang Café, Secret Recipe, and Old Town White Coffee that meet the need for 'eating out' and give in to nostalgia for heritage at the same time. According to the World Tourism Organization (UNWTO), the number of tourists in Malaysia has made a considerable leap from 5.56 million in

1998 to >28 million in 2017. In addition, domestic tourists are sensitive to food nostalgia. These catering concepts and their 'heritage' food products, loaded with cultural references, seem to benefit from this additional clientele. At the same time, tourists' expectations of local and 'authentic' foods are further accelerating the trend towards the patrimonialisation of foods (Poulain, 1997; Bessière, 2008; Bessière, 2018; Bessière & Tibère, 2013; Tibère & Aloysius, 2013; Ramli *et al.*, 2017). This context offers new opportunities for actors in the food industry and the catering sector, enabling them to develop new products and services such as healthy food or foods perceived to have cultural attributes, and to encourage shorter circuits between producers and consumers. It also exposes them to new social responsibilities in the face of the rise of NCDs in which food is a determining factor (Laporte & Poulain, 2014). Finally, it can be coined in the actions of the Malaysian food culture promotion by the Ministry of Culture and Tourism and in the multiplication of Malaysian cookbooks or the different components of Malaysia (Ibrahim, 1991; Sauw, 2014; Hutton & Invernizzi Tettoni, 2015; Teong, 2016).

2. Food cosmopolitanism: Malaysia is a multicultural food space where many great cultures, i.e. Indian, Chinese and Malay are mixed and among these big ensembles, other sub-divisions exist depending on the region of origin and religion. The relation to food is also crossed in these diasporic groups by systems of positive and negative tensions with the cultures of origin. With the superposition of different food cultures in the same social space, a food cosmopolitanism develops. Reducing distance in space not only increases the mobility of food and people at the national level (between regions, and between rural and urban areas), but also at the international level (between countries and continents). Mobility develops the

interconnection or intercrossing of food cultures, and in some contexts their hybridisation or even their creolisation, which constitutes a high degree of cultural cross-fertilisation and creates a new food culture (Tibère, 2016). One of the consequences of the development of tourism and the international hotel industry is to make available on Malaysia the urban territories as an offer to represent the European cultures (e.g. French, Spanish, and Italian), as well as the Asian cultures (e.g. Japanese, Chinese, and Korean), and transnational cultures such as Kentucky Fried Chicken. Kuala Lumpur thus establishes itself in a cosmopolitan universe that sometimes surprisingly mixes different food cultures, such as the advertisement on the front of a restaurant, which displays the expression of 'Italian Tapas'!

3. The rise of food anxiety: food modernity is accompanied by the telescoping of several dimensions likely to be at the origin of crises like the control of frauds, the management of food safety, the sanitary control of food, and the socio-technical controversies related to the used technologies in producing, processing, and marketing of foods (Poulain, 2018b). These different dimensions appear in the West at different times, and develop according to different rhythms. Management and administrative systems were then put in place (ministerial services for fraud repression, health crisis management or food security), and the skills of the populations themselves to choose, prepare, and use food subsequently evolved. In some Asian countries, the dimensions of food crises (fraud, food, and sanitary security and controversies) are simultaneously present and interact with one another to create unique contexts.

Furthermore, MFB data showed the importance of 'out-of-home' consumption practices in the society of Malaysia, which undergoes a compressed

modernisation process. MFB is a tool for observing the modernisation of the eating social space of this Southeast Asian society. It describes and follows the food model transformations, especially in the distribution of consumption places and in the process of individualisation practices. The fields of application are numerous, both in health and consumption. For example, regarding the fight against obesity, the prevention models developed in Europe (and extended to the United States), which are based largely on the valorisation of food in the family context, proved to be disconnected from the Malaysian social reality and might even be counterproductive. From the economic point of view, the data highlight an organisation of the food chain in which the relative weight of 'out-of-home' and 'out-of-home food' is especially important. It also points to the importance of social responsibility of 'out-of-home' catering actors from various forms of restoration to their agribusiness suppliers, in addition to the role they are playing in diet-related NCDs. The pattern of food consumption in Malaysia shows that the boundaries between 'out' and 'at home' can emerge in a very different way from the West. This translates, among other things, a variable distribution of weight among the actors in the economy of food Industry. In this particular case, the restaurateur and their devoted sources of supply have a significant weight in the organisation of this activity sector.

Finally, the Malaysian society with its multicultural characteristics (assigned as ethnicities through a long period of positive discrimination policy) arises as a privileged empirical field of observation for the analysis of the modernisation modalities of diet models among different ethnic groups. In other words, it makes it possible to identify changes

in the relative weight of sociological and cultural variables during modernisation. Malaysia is also a prime location for adapting tools to Chinese, Indian, and Indonesian food cultures. Therefore, MFB is the first step of the current development within the framework of the International Associated Laboratory French National Center for Scientific Research (CNRS): Food, Cultures and Health, an Asian Food Barometer (AFB). More broadly, through the study of these lifestyle mutations, rationale of supply and ways of eating, MFB also offers the opportunity to identify favourable conditions to the emergence of new forms of food crises (Simoulin, 2018; Augustin-Jean & Poulain, 2018).

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Authors' contributions

JPP, conceptualised the MFB, organised and supervised its realisation, wrote the first version of the article; CL, participated in the conceptualisation of the MFB, its realisation, the treatment of data and writing the article; LT, participated in the conceptualisation of the MFB, its realisation, the treatment of data and writing the article; EM, participated in the production of the MFB, the treatment of the data and the drafting of the article; NAR, participated in the conceptualisation of the MFB and the proofreading of the article; AAZ, did the scientific revision, proof writing and academic editing of the article; IMN, participated in the conceptualisation of the MFB and the proofreading of the article.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Understanding barriers towards the use of food labels among Saudi female college students

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ABSTRACT

Introduction: A food label is an important tool that provides nutritional information which influences consumers by promoting awareness on their diet and improving health status. This study aimed to assess nutrition knowledge level, food label usage, and the barriers that hinder the use of food labels among students in Health Colleges at the Princess Nourah Bint Abdulrahman University (PNU). **Methods:** A cross-sectional study was conducted among Health College students at PNU in Riyadh (Saudi Arabia). A total of 572 participants were interviewed through a validated questionnaire on social demographic characteristics, nutrition knowledge level, food label use, and barriers that hinder food label use. Statistical analysis was performed using SPSS (version 21), with statistical significance set at p -value <0.05 . **Results:** Only 27.4% of the participants stated that they always or usually use food labels when purchasing food products. Majority of the participants (59.4%) had moderate nutrition knowledge. Factors significantly associated to food label use were nutrition knowledge ($R^2=0.21$), attitude towards health value of the products ($R^2=0.35$), and taste ($R^2=-0.22$). About 41.0% of the participants indicated that time constraint was the main barrier for not using food labels, followed by no interest (31.3%), no need (27.8%), and difficult to use (24.8%). **Conclusion:** This study found that food label use was low among the participants. Nutrition knowledge supported food label use while time constraint was the main barrier that hindered the use of food label among them. Raising students' nutrition knowledge level through nutrition education programmes could promote food label use.

Keywords: Food label use, female university students, barriers, Saudi Arabia

INTRODUCTION

A balanced diet plays a significant role in promoting health and preventing both overnutrition and undernutrition-related diseases, such as obesity, type II diabetes mellitus, hypertension, and micronutrient deficiencies. According to Saudi Health Interview Survey (SHIS) (IHMS, 2013), such diseases are considered as major public health problems among the Saudi population. Furthermore, a more recent report by the

World Health Organization (WHO) (2018) indicated that 73% of all deaths in Saudi Arabia are related to non-communicable diseases. In addition, a 7-year meta-analysis study revealed that 63% of the Saudi population suffer from vitamin D deficiency (Al-Alyani *et al.*, 2018), while Al-Assaf (2007) demonstrated that iron deficiency anaemia is highly prevalent among adult Saudi women in Riyadh as 95.1% of this population have lower iron intake than the Dietary Reference Intake

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(DRI) recommendation. In response to this situation, policies and regulations have been put in place by the Saudi government in an attempt to combat nutrition-related health problems (Mokdad, 2016). With this regard and in line with Saudi Arabia's vision 2030, the Saudi Food & Drug Authority (SFDA) recently set up a strategy to regulate healthy dietary habits through reduction of sugar, salt, saturated, and trans fats in products (SFDA, 2018a), reinforcing the mandatory pre-packed food labelling that was implemented since 2007 (Al-Kandari & Jukes, 2009). In fact, the SFDA is the institution that oversees all matters related to foods including food laws and regulations, information and education activities for the consumers (Al-Kandari & Jukes, 2012). Saudi Arabia has officially adopted new standards for food labelling on pre-packed foods, as set by the Gulf Cooperation Council's Standardization Organization (GSO) (GSO9/2007), thus bringing the Gulf Cooperation Council's standards into closer compliance with the Codex Alimentarius guidelines. After that, in 2012, Saudi Arabia enforced the Gulf Cooperation Council's regulations concerning the disclosure of nutrition information on food labels (GSO 2233/2012), which was issued in the same year. Labelling requirements include nutritional information such as calorie counts, carbohydrates, proteins, fats, and other components that may affect the product's nutritional value or consumers' health or safety, and requirements for production and expiration dates (Al-Kandari & Jukes, 2009).

The aim of food labels is to provide dietary guidelines to the consumers and promote awareness of their eating habits, food quality, and daily food requirements (FDA, 2018). According to Lewis *et al.* (2009), increasing the use of food labels might improve health status and prevent nutrition-related problems. A recent systematic review that is

based on self-reporting of food label use confirmed the positive effects on consumers' dietary intake; reflected in the reduction of energy intake by 6.6%, total fat intake by 10.6%, other unhealthy foods by 13.0%. This strengthens the fact that food label is a way to influence consumers' purchasing decisions and ability to differentiate between healthy and unhealthy foods (Anastasiou, Miller & Dickinson, 2019). However, food labelling can only be effective if used properly and frequently by consumers. Miller and Cassady (2015) showed that the more nutrition knowledge consumers have, the more likely they are able to understand and use food labels to guide them towards making healthy decisions. However, there are barriers to the proper use of food labels that include shortage of time, difficulty to use, or no interest (Samson, 2012; Kristal *et al.*, 1998). Although food labelling and disclosure of nutrition information on food labels are mandatory in Saudi Arabia since 2007, few studies have been conducted on the use of food labels by Saudi consumers. Previous studies placed emphasis on special foods such as genetically modified food (Bakr & Ayinde, 2013), or on a specific ingredient such as hydrogenated oil (Kamel & Al Otaibi, 2018), or additives (Sachithananthan, 2017). In 2001, a research by Washi showed that the majority of Saudi consumers lacked knowledge in relation to the information on food labels such as nutritional content, serving size, and health claims. A pilot survey conducted among University students in Riyadh, Saudi Arabia to assess the importance and regular use of food labels showed that although 98% of responders confirmed the importance of food label, only 20% of them used it daily (unpublished data).

Overall, due to the gap in the existing literature related to how effective is the use of food label among Saudi consumers, the aim of this study was to assess the frequency of food label use among female students in Health Colleges at Princess

Nourah Bint Abdulrahman University (PNU) (Riyadh). Nutrition knowledge as a promoting factor and barriers hindering the use of food labels was also investigated in order to gain better understanding relating to food label use among this population. This will be useful in exploring whether efforts made at the institutional level (SFDA) through policies and regulations related to food labelling have been transcended and translated in terms of behaviour among Saudi consumers through frequent and effective use of food labels. Thus, emphasis will be made on elaborating appropriate recommendations to meet the expected effects of food labelling regulations on the health of the Saudi population.

MATERIALS AND METHODS

Study design and respondents

A cross-sectional study was carried out among Health College female students at PNU (Riyadh, Saudi Arabia), from January to March 2019, in which a total of 572 students participated. They were split among five Health Colleges based on convenient stratified sampling as follows: 159 students from the Health and Rehabilitation Sciences College, 141 students from the College of Nursing, 131 students from the College of Pharmacy, 89 students from the College of Medicine, and 52 students from the College of Dentistry.

Students having any health conditions such as a chronic diseases, food allergies, or micronutrient deficiencies, or who were following a weight loss/gain diet, or a diet to treat a medical condition were excluded from the study, because they would have most likely been using the food label.

The study was carried out after obtaining ethical approval from the Institutional Review Board committee of PNU (IRB Approval Number H-01-R-059/180365). Before taking part in the study, all participants were

provided with a consent form about the purpose of the study and their role in the study. The participation was voluntary, and the respondents had the option to refuse taking part in the study. There were no physical or psychological risks involved by taking part in this study. Furthermore, there were no direct benefits to the participants. All data collected from the participants were kept confidential.

Research tools

A valid questionnaire was used to collect data. It consisted of four sections.

Section 1

It included sociodemographic characteristics of participants such as age, specialty field, marital status, place of living and the responsibility of food purchasing.

Section 2

This section aimed to measure the nutrition knowledge of the participants. It contained multiple-choice questions with only one correct answer and was used to test the respondents' knowledge on the basic concepts of nutrition. The questions were adapted from the General Nutrition Knowledge Questionnaire (GNKQ) (Kliemann *et al.*, 2016). A 30-point score was used to evaluate the respondents' nutrition knowledge and based on the points scored, respondents were grouped into the following categories: scores of 0–10; 11–20; 21–30 points, indicative of low, moderate and high nutrition knowledge level respectively (Kliemann *et al.*, 2016).

Section 3

Questions in this section were related to the frequency of using the food label and nutrition information on food packages during purchasing. Questions were adapted from the Food and Drug Administration (FDA) Health and Diet Survey (FDA, 2014) and a study by Williams (2011). Frequency categories

Table 1. Sociodemographic characteristic, frequency of food label use and nutrition knowledge scoring of the studied population ($n=572$)[presented as% of total population ($n=572$), except for age as mean \pm SD]

<i>Variables</i>	<i>%</i>	<i>mean\pmSD</i>
Age (years)		21 \pm 1.8
Specialty		
Health and rehabilitation	27.8	
Medicine	15.6	
Nursing	24.7	
Dentistry	9.1	
Pharmacy	22.9	
Marital status		
Single	94.8	
Married	3.8	
Other	1.4	
Living with		
Family	91.8	
Alone in the university dormitory	8.2	
Person responsible for food purchase at home		
Myself	24.5	
Parents/relatives	68.5	
Maid/driver	7.0	
Frequency of food label		
Never	17.7	
Rarely	16.8	
Sometimes	38.1	
Usually	17.8	
Always	9.6	
Nutrition knowledge scoring		
Low	17.0	
Moderate	59.4	
High	23.6	

were never, sometimes, often, usually, and always. Then, on a 5-point Likert scale (Likert, 1932), (1=not important, 2=slightly important, 3=neutral, 4=important, 5=very important or 1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree), participants were requested to answer questions related to their attitudes towards the importance of price, health value, and taste during food purchasing, and the purchasing of unhealthy foods even after reading food labels.

Section 4

This last section focused on barriers that hinder food label use. Questions in

this section were adapted from the FDA Health and Diet Survey (FDA, 2014). The barriers covered the main reasons for not using the food labels; which were lack of time, difficulties encountered when using the food labels, no need to read food labels, and no interest in using food labels. In addition, participants who confirmed that food labels were difficult to use, or they do not need to use food labels were requested to further answer detailed questions related to these aspects. All answers were made on a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree) (Likert, 1932).

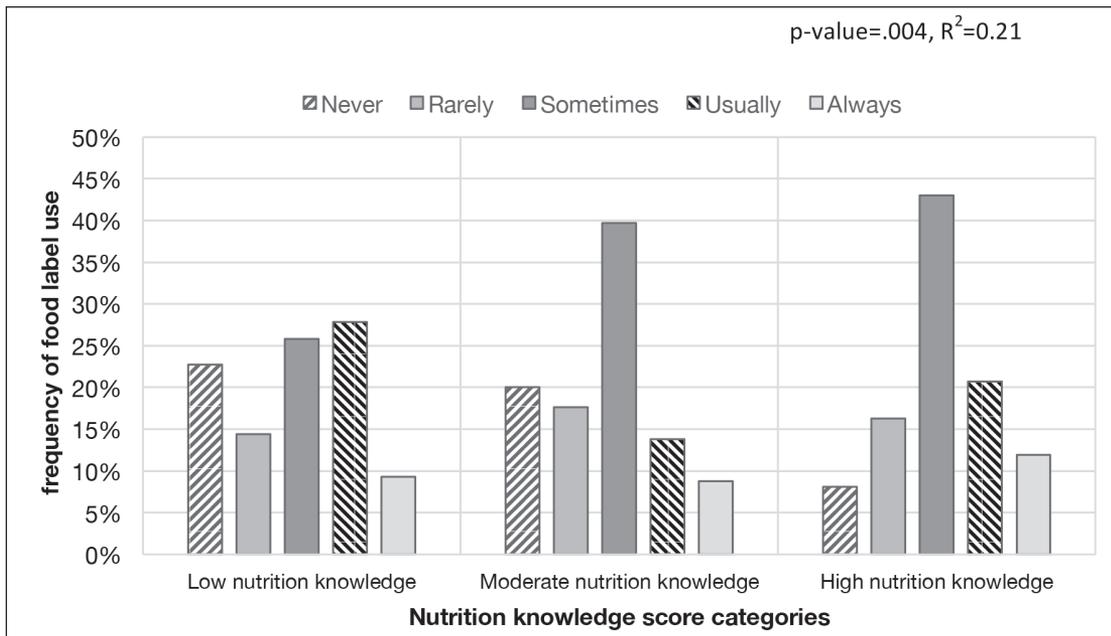


Figure 1. Frequency of food labels use according to nutritional knowledge of participants. Results are presented in percentage for each nutrition knowledge score categories

Reliability and validity of the questionnaire

The English language was used in the questionnaire, as Health College students were capable of understanding English. The questionnaire was pre-tested among 20 female students in order to guarantee its ease of understanding by the respondents. Minor modifications were made before its distribution. Reliability of the questionnaire was checked by Cronbach's alpha and this was equal to 0.76 in all sections, with a 95% confidence interval. The validity of the nutrition knowledge questions was confirmed by Pearson's correlation coefficient >0.3 for all questions.

Statistical analysis

Data was analysed by IBM SPSS statistics software version 21. Results were presented as percentage or mean \pm standard deviation (SD). Spearman's test was used to evaluate the correlation between categorical variables (frequency of food label use versus attitudes); while logistic regression was

performed to assess the correlation between categorical and continuous variables (frequency of food label use versus scoring of nutrition knowledge). Statistical significance level was set at p -value <0.05 .

RESULTS

Sociodemographic characteristics, food label use and nutrition knowledge

Table 1 summarises the sociodemographic characteristics of participants and frequency of food label use ($n=572$). The majority of participants were single (95.0%) and only 8.2% lived alone in a university dorm. The majority (68.5%) of participants reported that their parents were responsible for food purchasing. The frequency of food label use as stated by participants was 17.7% and 16.8% for never and rarely, respectively, while only 9.6% of the participants reported always using food labels. The majority of participants (59.4%) had moderate knowledge about general nutrition (Table

Table 2. Attitude towards the importance of price, health value, and taste during food purchasing among participants versus the frequency of food label use (n=572)

Aspect of the food product	Total population (%)	Frequency of food label use (%)					R ² , p-value
		Never (n=101)	Rarely (n=96)	Sometimes (n=218)	Usually (n=102)	Always (n=55)	
Health value							
Not important	6.8	19.8	8.3	2.8	2.0	5.5	0.35, <0.001
Slightly important	13.1	19.8	14.6	12.4	7.8	10.9	
Neutral	42.3	45.5	47.9	50.5	29.4	18.2	
Important	24.1	5.0	19.8	24.8	43.1	29.1	
Very important	13.6	9.9	9.4	9.6	17.6	36.4	
Taste							
Not important	3.0	4.0	3.1	1.8	2.9	5.5	-0.22, <0.001
Slightly important	3.5	2.0	0.0	1.8	7.8	10.9	
Neutral	15.0	7.9	7.3	17.4	20.6	21.8	
Important	22.9	16.8	27.1	22.9	20.6	30.9	
Very important	55.6	69.3	62.5	56.0	48.0	30.9	
Price							
Not important	8.0	13.9	3.1	7.8	3.9	14.5	0.11, 0.79
Slightly important	10.8	8.9	9.4	11.9	14.7	5.5	
Neutral	42.7	39.6	45.8	45.0	39.2	40.0	
Important	26.2	23.8	31.3	23.9	29.4	25.5	
Very important	12.2	13.9	10.4	11.5	12.7	14.5	

Note: Results are presented in percent for each response used a 5 point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree); correlation is calculated by Spearman test

Table 3. The barriers towards food label use during food purchasing among participants

Item	Response				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Reasons for not using food label (n=572)					
I don't have the time	20.1	6.6	32.3	21.5	19.0
It is difficult to use	33.9	14.5	26.7	17.7	7.3
I don't feel I need to use	31.5	12.8	28.0	14.2	13.6
No interest	30.4	11.0	27.3	13.3	18.0
Difficulty use of food label (n= 378)					
The print on the label being too small	30.7	6.9	25.7	20.1	16.7
I can't read the technical language that well	29.4	9.0	25.4	20.1	16.1
I don't know what to look for even if read	25.1	10.6	23.0	19.3	22.0
Reasons for not needing food label (n=392)					
I buy foods that I am are used to	16.3	1.8	13.8	29.8	38.3
I buy what I or my family likes	16.6	2.3	16.6	28.8	35.7
I am satisfied with my diet or health	26.3	8.2	26.0	20.7	18.9
I get product information from sources other than the food label	31.6	11.0	27.8	17.6	12.0
I don't think food labels are important	50.3	12.2	18.9	12.0	6.6

Note: Results are presented in percent of total population. Total population equals to 378 for 'difficulty use of food label', and equals to 392 for 'reasons for not needing food label'. Response categories used a 5 point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree)

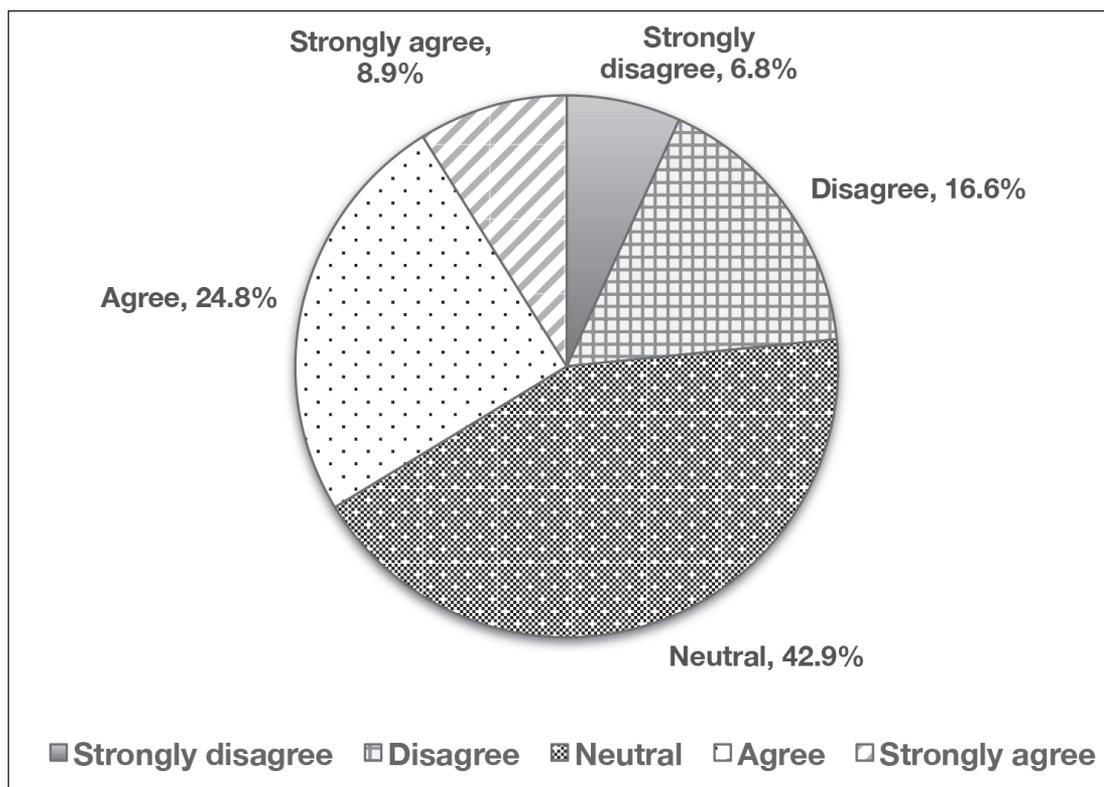


Figure 2. Distribution of respondent's attitude toward eating unhealthy food even in using food label ($n=471$). Results are presented in percent of total population. Response categories used a 5 point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree)

1). This scoring was significantly and positively associated with the frequency of food label use (p -value=0.04, $R^2=0.21$) (Figure 1), indicating that the higher the scoring, the more frequent the use of food labels. Interestingly, more than three-quarters of the participants who had high knowledge (75.6%) reported that they used food labels during purchasing.

Attitude towards the importance of price, health value, and taste during food purchasing

Results in Table 2 demonstrate that attitudes of participants towards health value and taste of food products were significantly correlated with the frequency of food label use during purchasing ($p=0.000$). Correlations for

attitudes towards these two aspects of food products were opposite as it was found to be positive for health value and negative for taste. The highest percentage for using food labels frequently (always) was observed among students who strongly agreed that the health value of a product is important (36.4% for "always" versus 9.9% for "never"). While in the case of taste, students who strongly agreed that this aspect is important during purchasing, showed the lowest percentage for the frequency of "always" in food label use (30.9% always versus 69.3% never).

Correlation was stronger with health value compared to taste ($R^2=0.35$ and $R^2=-0.02$, respectively). No significant correlation was obtained between price and food label use.

Barriers towards food label use during purchasing

As displayed in Table 3, about 41.0% of participants totally agreed or agreed that lack of time was the main reason for not using food label information during purchasing; followed by no interest (31.3%), no need (27.8%) and difficult to use (24.8%). Among the 378 participants who stated that food label is difficult to use, 41.3% of them confirmed that they did not know what to look for, even if they used it. In addition, small prints and technical language were both identified as barriers for not using food labels by similar percentages (36.8% and 36.2%, respectively). The reasons given for not needing to use food labels included being used to certain food products (68.1%) or buying favourite products, and what families preferred (64.5%). However, 62.5% of them stated that food label is important, despite their belief that there is no need to use it (Table 3). Interestingly, 33.7% of participants confirmed that they would still purchase unhealthy foods even if they used the food labels during purchasing (Figure 2).

DISCUSSION

This study was designed to assess the frequency of using food labels during food purchasing among Saudi female university students and to evaluate their nutrition knowledge, as well as the common barriers that hinder their use of food labels. In fact, the SFDA (2018) issued regulations for mandatory food labelling, including enforcing the display of calorie information in restaurants and coffee shops (SFDA, 2018a). Such policies are aimed at promoting public health awareness within the frames of Saudi Arabia's vision 2030 and WHO guidelines by enabling Saudi consumers to choose healthy foods to reduce nutrition-related diseases (SFDA, 2018b). Thus, food label could be a consumer's dietary guideline, which influences them to make healthier food choices (Anastasiou *et al.*, 2019).

Because of these great efforts advanced by SFDA, the assessment of Saudi consumers' use of food labels is urgently needed. Thus, the findings of the present research are relevant as they provide insights into Saudi consumers' awareness as revealed by the frequency of food label use and barriers hindering it.

This study showed that the frequency of food label use among female students was not high. The finding highlighted that only 27.4% of the participants used food labels, either "always" or "usually" when purchasing foods. The above finding is consistent with previous studies which suggest that the majority of participants only use food labels sometimes when buying food products (Bazhan, Mirghotbi & Amiri, 2015; Nurliyana, Norazmir & Khairil Anuar, 2011; Song *et al.*, 2015). In contrast, Samson (2012) and Basarir & Sherif (2012) concluded that participants who had a higher tendency of using food labels tended to pick products by themselves. While in the present study, less than a quarter (24.5%) of the participants was responsible for food purchasing at home.

In addition, a positive and significant association between food label use and nutrition knowledge level among participants ($p=0.004$) was found. The findings of this study revealed that 75.6% of students who had high nutrition knowledge level used food labels. This could indicate that nutrition knowledge is a promoter for food label use. Previous studies have confirmed similar findings where participants with higher knowledge were more likely to use food labels compared with those with low knowledge (Bazhan *et al.*, 2015; Barreiro-Hurlé, Gracia & de-Magistris, 2010; Norazlanshah *et al.*, 2013). However, interestingly, this is contrary to a study conducted by Nurliyana *et al.* (2011) who stated that no significant association was obtained between the level of nutrition knowledge and the use of food labels. A plausible explanation is that

besides nutrition knowledge, attitudes towards some other aspects of food products may influence food label use by consumers during purchasing. Indeed, the evidence from this study indicated that the more important the health value of the product, the more frequent is the use of food label. In contrast, when interest in taste increases, then there is a corresponding decrease in the use of food label. Moreover, this study found no association between food label use and the importance of price in the studied population. When purchasing foods, taste is the most important aspect among students (78.5%) compared to price (38.4%) and health value of the product (37.7%), which is consistent with the students agreeing to purchase unhealthy foods despite what they have read on the food labels (33.7%). These findings are supported by several studies, which stated that consumers grant taste the priority when purchasing food products (Jacobs, De Beer & Larney, 2010; Zaidi & Muhammad, 2012; Ababio, Adi & Amoah, 2012; Van der Merwe, Bosma & Ellis, 2014). Goodman *et al.* (2011) found that consumers were likely to give more attention to taste than nutritional information, which is in good agreement with the results of the present study.

However, besides factors that might promote food label use, there are a number of causes that impede it. The present study revealed that 40.9% of the students reported that the lack of time was the main reason for not using food labels. Other reasons were no interest, no need, and difficult to use, respectively. This might show that the majority of the students do not have the time to use food labels when purchasing and they assume that there is no need to waste time in using food labels because they know what to buy. In addition, Raseberry *et al.* (2007), Jacobs *et al.* (2010) and Barreiro *et al.* (2010) previously reported that shortage of time was the most common reason for not using food labels. Other authors

predicted that the most common reason for not using food labels among female students might be time restriction due to studying that can use up most of their time (Nurliyana *et al.*, 2011; Blitstein & Evans, 2006). The present findings suggested that the causes for 'no need to use food label' were because students were buying products that they or their family liked or the foods that they were used to. This could be due to the observation that for the majority of students, it was their families who were responsible for food purchasing at home (68.5%).

This study used a valid questionnaire and a substantial sample size ($n=572$), representative of the five Health Colleges. However, due to the convenient sampling technique and the specific study population, these results cannot be generalised and may not reflect the attitudes of other Saudi population groups. Thus, further investigation including non-Health College students are needed to obtain a comprehensive analysis on the use of food labels. It is also essential to highlight the epidemic growth of diet-related diseases such as obesity, diabetes and cardiovascular disease in the Kingdom of Saudi Arabia and the importance of managing them is considered to be one of the major public health issues. In order to reduce the incidence rate of diet-related diseases in long-term, the promotion of food label use, which acts as a preventive tool in offering information about nutritional value as a guidance for healthier dietary behaviours, can help consumers to improve their food purchasing behaviours.

CONCLUSION

This study demonstrated that the frequency of food label use during purchasing among Health College students at PNU was low. Nutrition knowledge and the importance of healthy foods seem to be a promoting factor to

food label use, while taste and lack of time were considerable barriers. Hence, emphasis on increasing the awareness towards health through nutrition education and/or individual counselling is needed to meet the expected results of SFDA's policies among the Saudi population. A plausible action would be a joining effort of Saudi stakeholders such as SFDA and the Ministry of Education to develop a policy to mainstream nutrition basics in all school curricula, as food knowledge is a predictor for increased use of food labels. As such, consumer awareness is a determinant that can be used to increase food label use, which will lead to healthier dietary options. And consequently, this will help reduce the prevalence of nutrition-related problems in the long term. On the other hand, food labelling should be revised to make it easier to read and be understood by the consumers.

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Authors' contributions

All authors provided substantial contribution in conception and design, or analysis and interpretation of data. They also work together in drafting the article or revising it critically for important intellectual content. Final review and approval of the version to be published was done by each of the authors.

Conflict of interest

The authors have no conflict of interest to be declared.

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REVIEW

The role of public health dietary messages and guidelines in tackling overweight and obesity issues

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ABSTRACT

Overweight and obesity in Malaysia pose serious threats to health. Prevalence has escalated to alarming levels in recent decades despite a multitude of public health dietary messages geared towards obesity prevention and health promotion. Gaps between health messages, messengers, and the public must be identified and closed to effectively combat obesity and overweight. This review article aims to examine public health dietary messages, guidelines, and programmes for the prevention of obesity in Malaysia, and explore potential reasons for the continued rise in its prevalence. Public health dietary communication in Malaysia has progressed and improved substantially over the years. However, most messages have been designed for the general audience, with little consideration of differences in physical, social, cultural, and environmental backgrounds, and varying levels of comprehension. We offer several recommendations to increase the effectiveness of public health dietary messages in fighting the obesity epidemic, based on a cross-sectoral, place-based approach that recognise the complexity of the underlying causes of obesity.

Keywords: Public health dietary messaging; obesity; Malaysia; place-based approach; cross-sectoral approaches

INTRODUCTION

Obesity has tripled worldwide since 1975, reaching epidemic proportions in both developing and developed countries; as of 2018, 13% of adults are obese and 39% overweight (WHO, 2018). Meanwhile, the prevalence of overweight and obesity among children and adolescents have risen from 4% in 1975 to 18% in 2016 (WHO, 2018). The Global Burden of

Disease Study (Ng *et al.*, 2014) reported a prevalence of overweight and obesity in Southeast Asia as 22.1% among men and 28.3% among women, with the highest rates in Malaysia at 48.3% and 48.6% for men and women, respectively. The 2015 Malaysian National Health and Morbidity Survey (NHMS) reported similar numbers, estimating the national prevalence of overweight and obesity in

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adults at 30.0% and 17.7%, respectively, for a total of 47.7% (IPH, 2015). In just two decades, the prevalence of overweight adults has doubled from 16.6%, while obesity has increased four folds from 4.4% (IPH, 1996). Malaysia has stated its intent to stop the rise in the prevalence of obesity by 2025 (MOH Malaysia, 2016). The US\$1-2 billion (RM4.26– 8.53 billion) spent to combat obesity in 2016, including direct and indirect costs, is equivalent to ~10-19% of the national healthcare expenditures (ARoFIIN, 2016). Public health messages around nutrition such as those issued by the Ministry of Health (MOH) are important as one of the range of efforts for health promotion and obesity. Yet, despite all these actions, obesity rates have continued to rise sharply.

Failure to halt the dramatic increase in the prevalence of overweight and obesity in Malaysia and worldwide has contributed to increased health risks for non-communicable diseases (NCDs) such as diabetes, cardiovascular diseases and cancers, as well as other health issues, consequently leading to higher morbidity and mortality rates. About 8% of total mortality each year is attributed by obesity (Beaglehole *et al.*, 2011). Beyond increased risk of obesity-related chronic diseases and poorer quality of life, the healthcare costs of treating obesity-related disease conditions are rapidly escalating. On average, obese Malaysian males and females lose about 6–11 years and 7–12 years of their productive life, respectively (ARoFIIN, 2016).

This paper reviews some of the public health dietary messages, guidelines, and programmes related to overweight and obesity in Malaysia. It identifies possible reasons for the continuing increase in its prevalence in the face of abundant public health messages and offers recommendations for a more systemic, place-based approach to slowing and reversing the rise in obesity.

Public health dietary messages

Public health messages related to nutrition and obesity in Malaysia

In recent decades, the Malaysia MOH has disseminated numerous public health messages, various sets of nutritional and dietary guidelines, and a series of programmes for the public and for health professionals. The National Plan of Action for Nutrition of Malaysia (NPANM) underlies Malaysia's strategy for addressing public health nutrition, and to date, three versions of the plan have been published since 1996 (NCCFN, 1996; NCCFN, 2006; NCCFN, 2016).

Table 1 compares the evolving aims of the three NPANMs and the evolution of the main areas of focus and facilitating strategies. In the 1996-2000 version, most NPANM targets and goals were to address nutritional deficiencies, with no set target for overweight and obesity. At that time, the prevalence of overweight and obesity were 16.6% and 4.4%, respectively (IPH, 1996). By 2003, these have increased to 26.7% and 12.2%, representing nearly two- and three-fold increases, respectively, in over just seven years (Azmi *et al.*, 2009). By the launch of the second NPANM in 2006, the national prevalence of overweight and obesity among adults were reported at 29.1% and 14.1% (IPH, 2006), with the prevalence of NCDs also on the rise. The new plan, shifted to meet the new needs accordingly, aimed to enhance the nutritional status of the entire population and also to prevent and control diet-related NCDs. NPANM II sets a population-level goal of not >30% overweight and not >15% obesity, of which these targets were not achieved. In view of the current critical situation, the third and most recent NPANM (2016-2025) has adopted a goal of *no further increase* in any obesity-related indicators, taking NHMS 2015 data as a baseline. It has also established new indicators, such as abdominal obesity for overweight and obesity among adults >60 years of age.

Table 1. Aims of the NPANM I, II, and III (1996-2000, 2006-2015, 2016-2025) and the evolution of the main areas of focus and facilitating strategies

Main objectives	<i>National Plan of Action for Nutrition of Malaysia (1996 - 2000)</i> [NPANM I]	<i>National Plan of Action for Nutrition of Malaysia II (2006 -2015)</i> [NPANM II]	<i>National Plan of Action for Nutrition of Malaysia III (2016-2025)</i> [NPANM III]
	<ul style="list-style-type: none"> • Designed to ensure optimal nutritional status of the population for human resource development towards the countries industrialisation process and development of a caring society by the year 2020 • Addresses both under and overnutrition • Nutrition targets and goals were mainly for child survival, protection, and development: malnutrition, anemia, iodine deficiencies, etc. 	<ul style="list-style-type: none"> • Designed to achieve and maintain optimal nutritional well-being of Malaysians • Addresses current and emerging issues in nutrition at that point of time where Malaysia is confronted with the problem of dual burden of malnutrition – underweight and overweight and obesity 	<ul style="list-style-type: none"> • Designed to address food and nutrition challenges in the country • Identified 46 nutrition indicators and set targets to be achieved by 2025 • Aims to strengthen food and nutrition security, enhance nutritional status, and reduce diet-related NCDs
<i>No change/ Maintained</i>	<i>Removed after NPANM I</i>	<i>Added into NPANM II</i>	<i>Added into NPANM III</i>
<ul style="list-style-type: none"> • incorporating nutritional objectives into development policies and programmes • improving household food insecurity • food quality and safety • breastfeeding • preventing and controlling specific micronutrient deficiencies • promoting appropriate diets and healthy lifestyles • assessing, analysing, and monitoring nutrition situations • reducing overweight and obesity and other diet-related NCDs 	<ul style="list-style-type: none"> • preventing and managing infectious diseases 	<ul style="list-style-type: none"> • complementary feeding practices for young children • strengthening research and development • strengthening institutional capacity in nutrition activities • ensuring nutrition and dietetics are practised by trained professionals 	<ul style="list-style-type: none"> • maternal nutrition • sustaining food systems to promote healthy diets • providing standard nutrition guidelines for various targeted groups • strengthening community capacity in nutrition activities

Whilst all three plans have taken on such basic goals as ensuring food quality and safety, and promoting appropriate diets and healthy lifestyles, the focal areas and facilitating strategies for nutrition have evolved in successive NPANMs (Table 1). For example, NPANM I prioritised the prevention and management of infectious diseases, while NPANM II addressed complementary feeding for children and promoted institution-building strategies to strengthen research, development, and capacity. NPANM III recognises the importance of systemic action and local context, promoting multidisciplinary teamwork that builds capacities and empowers communities, the inclusion of food systems frameworks in nutritional strategies, and the development of targeted guidelines for vulnerable groups.

The Malaysian Dietary Guidelines are an important strand of public health messages related to nutrition. Aimed primarily at health care providers, they are “intended to act as a tool for healthy eating promotion towards achieving the NPANM” (NCCFN, 2010). Established in 1999 with eight key messages designed to prevent nutritional deficiencies and chronic diseases, the Guidelines were revised and updated in 2010, splitting several of the original messages to more specifically emphasised messages, for example, the importance of daily physical activity and fruit consumption, and adding on four new guidelines, making a total of fourteen key messages (Figure 1). These changes reflect a better understanding of the origins of obesity and lifestyle-related diseases in Malaysia.

Another strand of public health nutrition promotion encompasses the visually-oriented Malaysian Food Pyramid and Healthy Plate, both aimed at the general public. The Malaysian Food Pyramid, first introduced in 1997 (Tee, 2011), is modelled on the United States Department of Agriculture’s

Evolution of dietary guidelines in Malaysia

(Malaysia Dietary Guidelines 1999 and 2010)

1. Eat a variety of foods within your recommended intake.
2. Maintain body weight in a healthy range.
3. Be physically active every day.
4. Eat adequate amount of rice, other cereal products (preferably whole grain) and tubers.
5. Eat plenty of fruits and vegetables every day.
6. Consume moderate amounts of fish, meat, poultry, egg, legumes and nuts.*
7. Consume adequate amounts of milk and milk products.*
8. Limit intake of foods high in fats and minimise fats and oils in food preparation.
9. Choose and prepare foods with less salt and sauces.
10. Consume foods and beverages low in sugar.
11. Drink plenty of water daily.
12. Practise exclusive breastfeeding from birth until six months and continue to breastfeed until two years of age.
13. Consume safe and clean foods and beverages.*
14. Make effective use of nutrition information on food labels.*

*Key messages that were introduced in the Malaysia Dietary Guidelines 2010

Figure 1. Evolution of dietary guidelines in Malaysia

(USDA) Food Guide Pyramid (USDA, 1992). Intended as a visual guide to assist the public in planning suitable daily food consumption in terms of choices and quantities, the current version of the pyramid is contained in the Malaysian Dietary Guidelines 2010 (NCCFN, 2010). In 2016, the Malaysian Healthy Plate (provide reference), modelled on the USDA MyPlate (Table 2), was released to supplement and in some ways supersede the Food Pyramid.

Table 2. Comparison of the Malaysian Food Pyramid and Malaysian Healthy Plate

Malaysian Food Pyramid 2010



Malaysian Healthy Plate 2016



The pyramid consists of four levels (from base to the top of the pyramid):

- Level 1 (base) – Cereals, cereal products, and tubers: Eat adequately, 4-8 servings/day
- Level 2 – Vegetables: Eat plenty, 3 servings/day
- Level 3 – Milk and milk products: Eat in moderation, 1-3 servings/day
- Level 4 (top) – Fish, poultry, meat, eggs, legumes: Eat in moderation, 1/2-2 servings of poultry/meat/eggs/day; 1 serving of fish/day, 1/2-1 serving of legumes/day
- Level 4 (top) – Fat, oil, sugar, salt: Eat less (no quantity recommended)

“Quarter-Quarter-Half” Concept

- Fill a quarter of a plate (round) with rice, noodles, bread, cereals, cereal products, or tubers, preferably wholemeal (carbohydrate-based).
- Fill another quarter of the place with fish, chicken, meat, or beans/legumes (protein-based).
- Fill half of the plate with vegetables and one serving of fruit.
- Complete the meal with a glass of plain water or a non-sweetened beverage, milk, or milk product.

Additional recommendations:

- Eat three (3) main healthy meals a day.
- Eat one to two healthy snack in between mealtimes if needed.
- Make at least half of your overall cereal and cereal products intake as wholemeal options.
- Eat non-fried and non-coconut milk based dishes everyday.
- Eat home-cooked foods more frequently.

Table 3. Total health expenditure (public and private sector) to providers of health services, 1997-2015 (RM Million)

	1997	2000	2003	2006	2009	2010	2011	2012	2013	2014	2015
	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
	Million	Million	Million	Million	Million	Million	Million	Million	Million	Million	Million
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Hospitals ^a	3,990 (48.21)	5,246 (44.84)	7,661 (42.64)	11,247 (47.94)	15,147 (49.18)	16,530 (47.35)	18,304 (48.26)	21,070 (50.59)	22,524 (51.12)	25,704 (52.25)	27,816 (52.87)
Nursing and residential care facilities ^b	2 (0.02)	3 (0.03)	10 (0.06)	12 (0.05)	6 (0.02)	13 (0.04)	16 (0.04)	20 (0.05)	2 (0.00)	2 (0.00)	1 (0.00)
Providers of ambulatory healthcare ^c	1,968 (23.75)	2,612 (22.33)	3,544 (19.72)	5,676 (24.19)	5,526 (17.94)	6,928 (19.85)	7,808 (20.59)	8,665 (20.80)	9,300 (21.11)	10,311 (20.96)	10,753 (20.44)
Retail sale and other providers of medical goods ^d	537 (6.49)	815 (6.96)	1,081 (6.01)	1,669 (7.11)	2,210 (7.18)	2,774 (7.95)	3,193 (8.42)	3,504 (8.41)	3,879 (8.80)	4,604 (9.36)	4,942 (9.39)
Provision and administration of public health programmes ^e	389 (4.70)	439 (3.75)	594 (3.31)	769 (3.28)	1,228 (3.99)	1,009 (2.89)	1,160 (3.06)	1,519 (3.65)	1,125 (2.78)	1,529 (3.11)	1,547 (2.94)
General health administration and insurance ^f	1,026 (12.40)	2,000 (17.10)	3,960 (22.04)	2,780 (11.85)	4,507 (14.63)	5,222 (14.96)	4,638 (12.23)	3,903 (9.37)	3,983 (9.04)	3,764 (7.65)	4,110 (7.81)
Other industries (rest of the Malaysian economy) ^g	104 (1.25)	124 (1.06)	175 (0.97)	203 (0.87)	275 (0.89)	326 (0.93)	389 (1.02)	433 (1.04)	509 (1.15)	554 (1.13)	539 (1.02)
Institutions providing health related services ^h	259 (3.12)	453 (3.87)	933 (5.19)	1,089 (4.64)	1,893 (6.15)	2,030 (5.81)	2,316 (6.11)	2,453 (5.89)	2,636 (5.98)	2,715 (5.52)	2,883 (5.48)
Rest of the world ⁱ	4 (0.05)	7 (0.06)	11 (0.06)	17 (0.07)	6 (0.02)	75 (0.22)	102 (0.27)	85 (0.20)	6 (0.01)	9 (0.02)	18 (0.03)
Total	8,277 (100.00)	11,698 (100.00)	17,969 (100.00)	23,462 (100.00)	30,796 (100.00)	34,909 (100.00)	37,927 (100.00)	41,652 (100.00)	44,063 (100.00)	49,193 (100.00)	52,609 (100.00)

Source: Malaysia National Health Account Health Expenditure Report 1997-2015 (MOH Malaysia, 2015)

^a Public and private hospitals^b Nursing care facilities including psychiatric care facilities, residential for mental health, etc^c Establishments providing ambulatory health care services directly to non-hospital settings, e.g. medical practitioner clinics, dental clinics, etc^d Pharmacies and retail sale/suppliers of vision products, hearing aids, medical appliances^e Health prevention and promotion services (public and private)^f Overall administration of health (public and private) and health insurance administration^g Private occupational health care and home care, etc^h Health training institutions (public and private)ⁱ Non-resident providers providing health care for the final use residents of Malaysia

Table 4. Total expenditure (public and private) on health by functions of health services, 1997-2015 (RM Million)

	1997	2000	2003	2006	2009	2010	2011	2012	2013	2014	2015
	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM	RM
	Million	Million	Million	Million	Million	Million	Million	Million	Million	Million	Million
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Services of curative care ^a	5,148 (62.20)	6,791 (58.05)	9,766 (54.35)	14,891 (63.47)	18,352 (59.59)	19,875 (56.94)	23,058 (60.80)	26,161 (62.81)	27,110 (61.53)	30,729 (62.47)	33,093 (62.90)
Services of long-term nursing care ^b	1 (0.02)	3 (0.02)	10 (0.05)	12 (0.05)	5 (0.02)	12 (0.04)	15 (0.04)	19 (0.05)	1 (0.00)	2 (0.00)	1 (0.00)
Ancillary services to health care ^c	2 (0.02)	14 (0.12)	84 (0.47)	197 (0.84)	232 (0.75)	234 (0.67)	335 (0.88)	325 (0.78)	347 (0.79)	676 (1.37)	704 (1.34)
Medical goods dispensed to out-patients ^d	956 (11.55)	1,349 (11.53)	1704 (9.48)	2,612 (11.13)	3,318 (10.77)	4,348 (12.46)	4,836 (12.75)	5,249 (12.60)	5,710 (12.96)	6,754 (13.73)	7,320 (13.91)
Prevention and public health services ^e	483 (5.83)	546 (4.67)	771 (4.29)	1,040 (4.43)	1,328 (4.31)	1,362 (3.90)	1,508 (3.98)	1,798 (4.32)	2,593 (5.88)	2,468 (5.02)	2,653 (5.04)
Health program administration and health insurance ^f	919 (11.10)	1,184 (10.12)	1,936 (10.77)	2,388 (10.18)	3,015 (9.79)	3,162 (9.06)	3,619 (9.54)	3,539 (8.50)	3,528 (8.01)	4,107 (8.35)	4,219 (8.02)
Capital formation of healthcare provider institutions ^g	501 (6.06)	1,357 (11.60)	2,773 (15.44)	1,317 (5.61)	2,714 (8.81)	3,831 (10.97)	2,169 (5.72)	2,009 (4.82)	1,808 (4.10)	1,472 (2.99)	1,434 (2.73)
Education and training of health personnel ^h	206 (2.48)	411 (3.52)	850 (4.73)	969 (4.13)	1,781 (5.78)	2,039 (5.84)	2,336 (6.16)	2,478 (5.95)	2,709 (6.15)	2,714 (5.52)	2,887 (5.49)
All other health related expenditures ⁱ	0 (-)	0 (-)	0 (-)	0 (-)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.00)	1 (0.00)
Total	8,277 (100.00)	11,698 (100.00)	17,968 (100.00)	23,461 (100.00)	30,798 (100.00)	34,908 (100.00)	37,926 (100.00)	41,652 (100.00)	44,063 (100.00)	49,193 (100.00)	52,609 (100.00)

Source: Malaysia National Health Account Health Expenditure Report 1997-2015 (MOH Malaysia, 2015)

^aCurative care provider at inpatient, outpatient, day-care, and homecare services (includes hospitals and clinics)^bLong term nursing care provider at inpatient, outpatient, day-care, and homecare services^cStand-alone laboratory, diagnostic, imaging, transport, and emergency rescue, etc.^dPharmaceuticals, appliances, western medicines, traditional Chinese medicine, etc.^eHealth promotion, prevention, family planning, school health services, etc^fAdministration at HQ, State health dept, local authorities, private insurance, etc^gGovernment & private provision of education and training of health personnel, including admin, etc^hResearch and development in healthⁱCategory to capture all other expenditures that not classified elsewhere

The Malaysian Healthy Plate was heavily promoted to the public through mass media, with a message of *suku-suku-separuh* (translated as “quarter-quarter-half”), referring to fractions of a typical plate: one quarter for meat or fish (protein-based foods), one quarter for grains or carbohydrate-based foods, and half for vegetables and a serving of fruit. The healthy plate concept is highly visual and relatable, and thus easier to understand and put into practice than the more abstract food pyramid.

Public health spending in Malaysia

One way to improve the visibility and impact of public health messages is to increase expenditures. While specific data on the spending on public health nutrition messages and the costs of nutrition-related diseases are difficult to access, evidence from other sources suggest that Malaysia spends far more on treatments than on prevention. For example, according to the providers of healthcare services in Malaysia from 1997 to 2015, expenditures on hospitals, ambulatory health care, medicines, and medical appliances greatly exceeded the expenditure on health prevention and promotion services (Table 3). Indeed, expenditure on hospital treatments amounted to 50% or more of the total health expenditures (including public and private sectors), while <5% was spent on the provision and administration of public health programmes. Over the same period, similar trends were seen for total health expenditure by the function of health services (Table 4). About 55-65% of expenditure was for services of curative care, whereas just 4-6% was spent on prevention and public health services (Jackson & Shiell, 2017).

While these figures would seem to indicate a low level of public health spending in Malaysia, they are actually considered to be fairly high with respect to the average share of total healthcare spending directed to prevention services in the Organisation for Economic Co-

operation and Development (OECD) countries, where in most cases <3%. Indeed, health expenditure data must be interpreted with caution. For one, these data measure only expenditures by the health agencies, excluding spending by other agencies or other actors that may promote public health. For another, public health spending feeds into the systemic causes of health and is likely to have non-linear effects. For example, greater spending on public health promotion, including dietary messages, is likely to extend life expectancy. As such, individuals encountering the medical system may be older on average, with ailments that are more expensive to treat. Thus, high expenditures on treatment could potentially be indicative either of under-spending on prevention, or of a highly efficient system of prevention. More careful analysis of this issue in the Malaysian context would be valuable.

Evolution and controversy in dietary guidelines

Nutritional and dietary guidelines have evolved significantly over the past century, in parallel with greater understanding of the pathophysiological underpinnings of ill health. Modern nutritional science began with a strong focus on single-nutrient deficiencies and a concern over food shortages (Mozaffarian & Forouhi, 2018). The isolation of Vitamin C as a cure for scurvy in 1932 was followed by the identification of other single-nutrient deficits related with health issues, such as Vitamin A deficiency with night blindness, Vitamin D with rickets, thiamine with beriberi, and niacin with pellagra (Mozaffarian & Forouhi, 2018). These relatively simple successes inspired a reductionist approach to nutritional science, in which the relevant nutrient for a given disease was identified and its target intake was established (Messina *et al.*, 2001). This information was translated into simple messages for public consumption.

As such, diseases were progressively eradicated through advances in nutritional science and improvements in farming and food production. However, other issues began to gain in prominence. Perhaps unsurprisingly, the reductionist approach that had previously been so successful was applied to these issues. This was readily seen in the 1980 United States Dietary Guidelines (USDA, 1980), in which the public was instructed to avoid fats (including saturated fat and cholesterol), which received the lion's share of the blame for heart disease and obesity epidemics. Guidelines for dietary fat were first introduced by the United States and United Kingdom Governments with the aim of reducing the prevalence of coronary heart disease. Despite a lack of evidence from randomised controlled trials to support such guidelines, they have prevailed for 40 years (Harcombe *et al.*, 2015). The Malaysian Dietary Guidelines closely followed the United States guidelines, limiting the intake of foods high in fats and minimising the use of fats and oils in cooking. The Malaysian Food Pyramid also recommends reducing the intakes of fat, oils, sugar, and salt, although exact quantities are not mentioned. In the meantime, the 1980s saw an accelerating increase in obesity and overweight in the United States and other industrialised nations, and the emergence of chronic diseases related to overnutrition (Mozaffarian, 2017).

Clinicians are now questioning these existing food guidelines, which, in addition to adopting a reductionist perspective that now seems inadequate, are over-reliant on observational studies and small-scale, short-term interventions. Such studies are susceptible to confounding factors and errors in self-reported dietary assessments, and thus have questionable relevance to the real world (Mozaffarian & Forouhi, 2018). One major shift in nutritional thinking has been with respect to the role of fat. Indeed, there is

evidence that restricting total fat intake leads to higher carbohydrate intake, resulting in increases in obesity and diabetes (Harcombe, Baker & Davies, 2017). In a systematic review and meta-analysis across low-, middle-, and high-income countries, Sartorius *et al.* (2018) concluded that a high-carbohydrate diet, or an increased percentage of total energy intake in the form of carbohydrates, correspondingly increased the odds of obesity. While current opinions are not unanimous, this and numerous other findings question the prevailing assumptions and messages on good dietary practices. Such scientific debate over complex nutritional issues is inevitable and ought to produce better knowledge over time. However, it has also contributed to an ever-changing set of dietary recommendations, in which a nutrient is labelled harmful at one point in time, then healthy, then harmful again, causing public confusion and scepticism about scientific claims regarding nutrition (Mozaffarian, 2017). This confusion has been compounded by the accumulation of increasingly complex and nuanced findings which are more difficult to communicate than previous issues around single-nutrient deficiencies.

The controversial role of the food industry in public health dietary messages

Dietary guidelines from governments and advocacy organisations, themselves often muddled, compete with messages from other sources that ends up misinforming and confusing the public. In some cases, the food industry exacerbates this situation, including through promotion of unhealthy products, misleading marketing campaigns, targeting of children and other susceptible groups, corporate lobbying, co-opting of organisations and social media through financial support, and attacks against science and scientists. This may cause increasing distrust towards health

professionals and reluctance among the public to accept public health messages (Crossley, 2002).

One prominent example of the influence of the food industry is the aggressive food marketing tactics used to promote junk food consumption among children. For instance, in 2012, the United States's fast food restaurant industry spent \$4.6 billion on advertising, while combined advertising on so-called "healthier" foods, including milk (\$169 million), bottled water (i.e., as an alternative to soft drinks) (\$81 million), vegetables (\$72 million) and fruit (\$45 million), was less than one-twelfth that total (Harris *et al.*, 2013). An average child in the United States watches about 4,700 food-related advertisements per year, of which 84% are about junk foods (Harris *et al.*, 2015). Equivalent data on food marketing in Malaysia are not available at present, but it seems likely that unhealthy food advertising is equally predominant, if not more so, in this context. While powerful food companies have begun to be criticised and regulated in wealthier nations, less-developed countries remain vulnerable, often lacking junk food marketing policies, in part because they do not have the financial wherewithal to combat the well-resourced food industry. Less-developed countries also generally have a higher fraction of young people, who are more vulnerable to aggressive marketing tactics, and will therefore see higher undesirable impacts on them (Kovic *et al.*, 2018).

Another conspicuous example involves sugar-sweetened beverages (SSBs), a top contributor to overall sugar consumption (Baker & Friel, 2014). SSB consumption has been reported to be associated with increased waist circumference and other cardiometabolic risk factors, independent of physical activity levels and dietary patterns (Loh *et al.*, 2017). However, in industry-sponsored research on the health effects of SSBs (Bes-Rastrollo *et al.*, 2013)

and artificial sweeteners (Mandrioli, Kearns & Bero, 2016), the likelihood of research conclusions being favourable to the sponsor is higher than in non-industry-sponsored studies. Children and adolescents are frequent targets of SSB marketing strategies. This is critical because taste preferences are formed during youth and adolescence, and habitual exposure to SSBs can lead to unhealthy lifetime dietary habits (Gostin, 2018). Indeed, Brownell and Warner (2009) found that the food industry purposefully target youth populations to lock in new generations of consumers, a strategy previously adopted with much success by the tobacco companies.

Even when the food industry promotes healthier foods, it is usually done in ways that rely on reductionist messages that are easy to grasp, and that promise to improve health regardless of dietary and lifestyle context. The boom in the vitamin and dietary-supplement industry also relies on such marketing, despite a lack of evidence that these products benefit the general population (Jenkins *et al.*, 2018). Similarly, the benefits of other so-called health foods and diets, including juices and gluten-free diets, have frequently been overstated and taken out of their context of the original research (Freeman *et al.*, 2017). Such messages are further reinforced by dietary advices presented in the media, often based on the weakest forms of evidence, and therefore contributing to public misconceptions about food and health (Cooper *et al.*, 2012).

Cross-sector approaches in improving public health dietary messages

To develop effective messages to combat obesity, it is necessary first to understand the systemic factors that give rise to obesity. Public health research, recommendations, and interventions relating to overweight and obesity prevention and treatments are often based on a simple energy balance model which neglects the complex physiological,

behavioural and environmental systems that are involved (Hafekost *et al.*, 2013). Human physiology is evolutionarily adapted to food-scarce environments and is regulated at several levels by complex, multiple feedback mechanisms that homeostatically regulate energy balance to maintain body weight, making weight loss difficult (Flier, 2017). One example of such regulatory mechanisms is the effect of calorie restrictions on resting metabolic rate, which decreases energy expenditure in response to reduced energy input (Martin *et al.*, 2011; Martin *et al.*, 2007). Even when weight loss is achieved, the compensatory physiological mechanism responses to perceive food scarcity during dieting, which then encourages weight gain up to a year later. These physiological adaptations may be poorly suited to modern human habitats that promote high energy intake and low energy expenditure, characterised by “an essentially unlimited supply of convenient, relatively inexpensive, highly palatable, energy-dense foods”, combined with lifestyles that require only minimal levels of physical activity for survival (Hill & Peters, 1998; Peters, 2003; Cohen, 2008). For this reason, Hill and Peters (1998) remarked that the culprit in the increasing prevalence of obesity is the environment that promotes obesity-causing behaviours. Since we are unable to change our physiology, it is the obesogenic environment that must be “cured” to stop and reverse the obesity epidemic (Hill & Peters, 1998). Indeed, while poor dietary habits and inadequate physical activity are known contributing factors to the development of obesity and many NCDs (Booth, Roberts & Laye, 2012; Lachat *et al.*, 2013), public health professionals generally agree that genetic, biological, and psychological changes at the individual level are insufficient to explain the rapid modern rise in obesity rates. Therefore, the obesity epidemic must originate in a broader environmental, societal, and policy context (Koplan *et al.*, 2005;

Novak & Brownell, 2012; Kumanyika, Libman & Garcia, 2013). A systems perspective, capable of recognising the shape and potential impacts of feedback mechanisms, is required to navigate these issues.

It is important to consider how health messages feed into the physiological-environmental system that underlies obesity and the conditions necessary for information to be effective in this context. Public health messages aimed at reducing obesity must transcend an implied information-deficit model which assumes that supplying basic knowledge on nutrition is enough to achieve change. Rather, such messages are best understood as attempts to convince a very broad, diverse audience to make behavioural and lifestyle changes that are both difficult and at odds with their contextual cues and incentives. This differs from traditional marketing, which delivers uncomplicated, attractive messages to targeted audiences, and it should be no surprise that health messages achieve lower response rates (Kelly & Barker, 2016). This problem is compounded when health sector messages compete against those from commercial food and “health” industries. The latter promote simpler products while also generating profits, allowing the private sector to far outspend the health sector in this context. At present, guidelines for health promotion focus on communication techniques, such as limiting the number of ideas to avoid confusing readers (US Department of Health and Human Services, 2006), reducing jargon and technical language, using active voice and conversational style, and providing concrete examples (Wigington, 2008). Indeed, beyond failing to enable healthier behaviours, poorly crafted messages may contribute to negative self-perceptions and, in the process, generate more pervasive problems (Penney & Kirk, 2015; Rudolph & Hilbert, 2017). Yet, despite its importance, such techniques do not

address the broad range of obstacles in the messaging environment.

Because knowledge is necessary, but not sufficient, to change behaviour (Worsley, 2002; Patton, 2008), messages targeted at individual behaviour need to be accompanied by strategies that create contexts where people are encouraged or naturally predisposed to act on these messages. Therefore, health communicators also need to consider how to influence the key actors who shape these environments. For example, the failure of town and transport planners to consider health issues in, for instance, the design of parks, recreation centres, and other public spaces has been seen as a cause towards the rise in the prevalences of obesity, NCDs, and sedentary behaviour (WHO, 2004). A wide range of stakeholders, both public and private, at the federal, state, and municipal levels, must play a role in halting the obesity crisis. Physical, social and cultural environments associated with work (Schulte *et al.*, 2007; Hyun & Kim, 2018), food (Mattes & Foster, 2014; Steeves, Martins & Gittelsohn, 2014), family (González Jiménez *et al.*, 2012; Huang *et al.*, 2017) and community (Yoon & Kwon, 2014) can all enable and constrain individual choices and behaviours that affect obesity. For example, in Malaysia, the widespread practice of serving sweet and savoury snacks at morning and afternoon tea during functions, conferences and meetings enables over-consumption of foods, which also cements frequent eating as a social norm. Working hours (Cheong *et al.*, 2010), availability of fast food (Abdullah *et al.*, 2015), and school nutrition (SCHEMA, 2018), among other factors, also play key enabling/constraining roles in Malaysia. Health messages and other policy interventions must target these physical, social and cultural environments, connecting actors and creating new feedback links to reshape systems in ways that promote health.

Within Malaysia there is such heterogeneity in the sociocultural environments that both the messages and the way they are communicated must be tailored to the local contexts, highlighting the importance of place-based thinking. Indeed, rates of obesity in Malaysia vary by geographical locations and ethnicity (IPH, 2015), and these differences are greater than can be explained by simple urban/rural differentiation. Varied diets and cultures (Nurul Fadhillah, Teo & Foo, 2016; Lee, 2017) imply that the changes needed to achieve healthy and socially-acceptable eating habits and lifestyles may be very different for different ethnic and social groups. Similarly, identifying the appropriate form of messages and messengers for a target group is important and requires local knowledge (WHO, 2017). Acquiring and using this knowledge depends on early and consistent community engagement and participation in both research and policy processes, before problems and potential solutions are formulated (Bodison *et al.*, 2015). Accounting for the particularities of place will better allow for the development of targeted and tailored messages, programmes, guidelines, and interventions to meet age, gender, culture, socioeconomic, and geographical needs.

Recommendations for improving public health dietary messages in Malaysia

To make dietary health messages in Malaysia a more effective vehicle for change, we suggest three broad strategic actions: building capacity and receptivity for complex ideas, mobilising a diversity of messengers, and implementing key policy interventions that target the food environment.

Creating receptivity for complex ideas

While health messages should be simple to enhance communication, many important dietary messages are

inherently complex. In keeping with the systems view of public health dietary messages outlined above, various actions could be taken to improve the efficacy of messages in Malaysia without making them simplistic. First, an ability to understand complex messages needs to be developed within the community. Reductionist thinking continues to dominate science curricula, shaping the types of evidence people expect to see and are receptive to. Systems thinking, complexity, and holistic approaches to problem-solving could be introduced in school science curricula, for example in relation to biology, metabolism and nutrition (Fardet & Rock, 2014). In the long term, exposure to these concepts can create an ability to understand the interconnected concepts necessary to address present and future nutrition challenges. While rewriting basic curricula will take years, if not decades, the cost of nutrition-related diseases, to say nothing of other complexity-related societal challenges, warrants such an effort. A body of evidence suggests that such concepts can be understood by lay people, practitioners, and students, when given the appropriate pedagogy (SCHEMA, 2018; Newell & Siri, 2016). Second, it is still necessary to simplify complex messages, without making them simplistic, to meet existing capacities for comprehension. The Malaysia Healthy Plate is a good example of such translation. Further successes will depend in part on the involvement of local community leaders and members, as called for in NPANM III.

Mobilising diverse messengers through a multi-sector approach

As food is deeply tied to a wide range of social and cultural values, a multi-sector approach that addresses diet from a broader set of perspectives could increase effectiveness of dietary messages. While the MOH has actively fought overweight and obesity, gaps remain and these could be filled in by other ministries which

have historically been less engaged on this issue, but whose activities and responsibilities have consequences for urban health. These would include the Ministries of Urban Well-being, Housing and Local Government; Education; Finance; Transport; Women, Family and Community Development; Agriculture and Agro-Based Industry; and Youth and Sports. Many of these government ministries have access to different community organisations, and their contacts could be used to deliver messages and implement interventions specific to the target communities. A good example is the KOSPEN programme, a collaboration between the MOH and the Ministry of Rural Development to recruit and mobilise community health volunteers (MOH Malaysia, 2016).

The food industry is a key player in shaping the food environment and has often (though not always) done so in ways that undermine health messages. Indeed, the United States Centers for Disease Control and Prevention (CDC) acknowledges that the food industry's "expertise, reach, and innovation can help address challenges in food production, formulation, and distribution; facilitate greater innovation for public good; and build capacity" despite the potential for bias (CDC, 2018). Nevertheless, partnerships between the health sector and the food industry must be governed by clear principles to avoid actions and perceptions that would compromise health promotion goals (Mozaffarian, 2017; CDC, 2018; Freedhoff & Hébert, 2011).

The Malaysian health sector should also consider how to engage with the so-called public health activists "influencers", celebrity nutritionists, politicians, and food bloggers, to name a few, to encourage them to use messages based on best available evidence. These influencers have the potential to shape societal paradigms and purchasing choices, thus influencing and changing industry practices (Sbicca, 2012; Byrne,

Kearney & MacEvelly, 2017; Johnstone & Lindh, 2018).

Complementing messages with regulatory and fiscal policy

Regulation is an important mechanism for shaping the nutrition information environment to catalyse desired behaviours. Yet, ensuring the accuracy and credibility of messages can be challenging. A 2010 WHO resolution, endorsed by 192 United Nations member states, urged the regulation of food and beverage marketing to children to address the childhood obesity epidemic (WHO, 2010). However, many countries rely on the food industry's self-regulation in marketing (Hawkes & Lobstein, 2011). Malaysia, for example, has implemented food advertising regulations such as banning fast-food advertisements on children's television programmes, yet the Malaysian MOH has also endorsed self-regulation in the food industry. A prominent example is the Malaysian Food Manufacturing Group's "Responsible Advertising to Children – Malaysia Pledge" (Food Industry Asia, 2012; Food Industry Asia, 2013), the effects of which have not been studied. In some cases, the source of funding for nutritional research is likely to create conflicts of interest. For example, the MOH endorsed a popular malt drink, produced by a large multi-national company and marketed as a nutritious "Healthier Choice" made headlines in 2018, when a national controversy erupted over this drink's sugar content (Thiagarajan, 2018). Simultaneously, it came to light that the company in question also funds substantial nutrition research in Malaysia. This research included a study claiming correlations between consumption of malt drinks, physical activity and micronutrient intake among Malaysian children (Hamid *et al.*, 2015). Such findings may be legitimate; for example, there might be cultural factors

in this population associated with both malt-drink consumption and physical activity that explain the observed correlations. Nevertheless, results like this raise suspicion of conflicts of interest when there are perceived as lacking in transparency or external accountability (Mozaffarian, 2017). Indeed, such situations can also create suspicion of otherwise non-controversial results. Advertising regulations and MOH endorsements must be seen to be based on reliable and unbiased research to maintain the credibility of health promotion information.

Subsidies and taxes can also reinforce or subvert health messages and the capacity of the target audience to act upon them. They must be considered in the local economic and political context. For example, the WHO recommends restricting sugar consumption to <10% of total energy intake, and advocates a further reduction to <5% (WHO, 2015). Yet, sugar consumption worldwide exceeds these levels. Indeed, the Malaysian per-capita sugar consumption is among the highest in the world (11-19 tsp/day) (Swarna Nantha, 2014; Amarra, Khor & Chan, 2016), which is approximately 9-15% of total energy intake, (assuming it is 2000kcal/day). One response has been to tax products with high sugar content, such as SSBs, and this has been effective in some contexts (Colchero *et al.*, 2017; WHO, 2017; Gostin, 2018). Yet, in Malaysia, the price of sugar is perceived to broadly affect food prices, making it an important political issue on a wider scale. In fact, sugar was subsidised until 2013, and Malaysia still maintains a price ceiling on sugar, with politicians continuing to advocate subsidies (Anon, 2017) or lowering of this ceiling (Ganeshwaran, 2018). At the same time, SSB taxes have been studied by MOH in the past, and have been proposed again recently in response to the rising diabetes rates

(Anon, 2018). The contrasting positions on sugar prices and SSB taxes highlight the conflicting priorities between the trade and health arms of the Malaysian Government, illustrating the need for coordinated policies and mainstreaming of health in all government actions.

Subsidies can provide an effective complement to taxation in promoting better nutrition. Although white rice is culturally far more popular, perceived as finer and more desirable, but high consumption of white rice has been shown to increase type II diabetes risk, particularly in Asian populations (Hu *et al.*, 2012). So, in neighbouring Singapore, the Health Promotion Board has coupled messages on the consumption of brown rice and other whole grains with subsidises for these staple ingredients in the food service industry (Singapore Health Promotion Board, 2018). As brown rice carries a higher price tag, in part due to the economies of scale, thus this subsidy attempts to shift private sector practices to reinforce the health messages on rice consumption. Such strategies are worth exploring in Malaysia, where many consumers have high price-sensitivity, and the direct cost of diabetes alone is estimated at RM 2.04 billion annually (Feisul Idzwan *et al.*, 2017).

CONCLUSION

Being overweight or obese increases the risk of many health problems and imposes significant economic and social costs on the society. The alarmingly high prevalence of overweight and obesity in Malaysia thus represents a serious threat, not only to the health of its citizens, but to achieving other societal aspirations, including the United Nations Sustainable Development Goals (United Nations, 2015). This article reviewed public health dietary messages and guidelines connected to overweight and obesity issues, and examined gaps

in some of these messages. Although public health dietary communication in Malaysia has progressed and improved substantially over the years, most messages have been designed for the general audience, with little consideration of differences in physical, social, cultural, and environmental backgrounds, and varying levels of comprehension. Such messages also compete with promotional information disseminated by profit-making food and “health” industries. We suggest that cross-sector approaches grounded in an appreciation of local context can offer solutions to make dietary health messages more effective, in particular by increasing understanding of the complex determinants of obesity, taking advantage of the systemic roles of multi-sector stakeholders, and implementing specific policy interventions that target the Malaysian food, social-cultural, and environmental contexts.

List of abbreviations

CDC, United States Centers for Disease Control and Prevention; MANS, Malaysian Adults Nutrition Survey; NCDs, Non-communicable diseases; MOH, Ministry of Health; NHMS, National Health and Morbidity Survey; NPANM, National Plan of Action for Nutrition of Malaysia; SSBs, Sugar-sweetened beverages; USDA, United States Department of Agriculture; WHO, World Health Organization

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Authors’ contributions

All authors contributed to the paper and approved the final draft of the manuscript.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Development of a new questionnaire to assess childcare providers' KAP regarding infant and young child feeding

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ABSTRACT

Introduction: The integration of infant and young child feeding into childcare settings is important to the overall wellbeing of a community. To our knowledge, there is no questionnaire at the national context specifically on the knowledge, attitude and practice (KAP) of infant and young child feeding among childcare providers. Pre-existing questionnaires are unsatisfactory due to different target populations and validation approaches. This study aims to develop a new questionnaire for assessing the KAP regarding infant and young child feeding among childcare providers in Malaysia. **Methods:** A new questionnaire on childcare providers' KAP was developed using literature review, expert opinions, and a theoretical framework. It was developed using a modified Delphi technique in five phases: 1. Identification of the domains, 2. Verification of the identified domains, 3. Definition of the domains, 4. Identification of relevant and representative items for each domain, and 5. Final verification of the domains and items, followed by a pre-survey evaluation. **Results:** The final items were verified by experts with references to relevant literatures, other questionnaires, and experts' experiences. A total of 236 items were selected after consideration of their relevancy and representativeness: 104, 90, 42 items addressing knowledge, attitude, and practice, respectively. The questionnaire was named *Borang Kaji Selidik Pemakanan Bayi dan Kanak-kanak dalam kalangan Pengasuh*, or IYCF-CCPQ. **Conclusion:** The IYCF-CCPQ is a newly developed questionnaire to measure childcare providers' KAP regarding infant and young child feeding.

Keywords: KAP, infant feeding, childcare provider, questionnaire, development

INTRODUCTION

Infant and young child feeding (IYCF) includes all forms of infant feeding, including breastfeeding and complementary feeding. According to the public health recommendations issued by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) in 2003, optimal IYCF consists

of exclusive breastfeeding for the first 6 months of an infant's life, followed by the combination of breastfeeding with safe and nutritionally balanced complementary foods up to 2 years of age or beyond. These recommendations are to support the optimal growth, development, and health of children (WHO, 2003).

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Every woman has the right to decide how to feed her child and to receive information about the support available to her; this will help her when she re-enters the workforce (Quisumbing *et al.*, 1995; WHO, 2003; Chilton & Rose, 2009). Nowadays, with more women in the workforce, which was reported to be about 53.6% in 2014 (DOSM, 2014), families have become more reliant on child care services (Capizzano & Adams, 2000; National Population and Family Development Board, 2014). Consequently, the responsibility for IYCF is shared between parents and childcare providers (Freedman & Alvarez, 2010). Therefore, it is important to integrate the roles of parents with childcare providers to support the proper implementation of quality IYCF in childcare and daycare centres (Clark *et al.*, 2008; Lucas *et al.*, 2013; Asis, Al-Sadat & Abdul Majid, 2016).

The protection, promotion, and support of IYCF are essential to public health. It is important to explore the potential of childcare providers in assisting with IYCF as a form of primary support to working mothers after they have returned to work. However, little is known about these childcare providers' knowledge, attitudes, and practices (KAP) regarding IYCF, both globally and nationally. There is also a lack of evidence about the factors affecting the KAP regarding IYCF of childcare providers in Malaysia.

In order to facilitate data collection and the answering of research questions on this topic, a questionnaire needs to be designed and properly validated (Giesen *et al.*, 2012). In searching for valid, reliable questionnaires measuring childcare providers' KAP regarding IYCF, we found a number of questionnaires that varied significantly in their domains, theoretical backgrounds, and validation approaches. Furthermore, most pre-

existing questionnaires for childcare providers were developed in the Western countries (Clark *et al.*, 2008; Freedman & Alvarez, 2010; Lucas *et al.*, 2013). Given that the educational, socioeconomic, and cultural backgrounds of childcare providers in Malaysia differ significantly from those of Western countries (Clark *et al.*, 2008; Freedman & Alvarez, 2010; Lucas *et al.*, 2013), hence, the adoption of these questionnaires to a Malaysian context is not appropriate or practical.

With that, our aim is to develop a new questionnaire that will be used to assess the KAP regarding IYCF among childcare providers in the northeast part of Peninsular Malaysia. Proper development and validation will result in a well validated, culturally sensitive questionnaire designed specifically for our local childcare providers.

MATERIAL AND METHODS

Questionnaire development

The new questionnaire was developed in Kota Bharu, Kelantan from November 2016 to April 2017. This questionnaire was developed in the Malay language, structured and designed specifically to assess childcare providers' KAP regarding IYCF. The questionnaire was developed using a modified Delphi technique; which was then evaluated through cognitive debriefing and pre-testing. The questionnaire did not require any translation since it was developed in the native Malay language.

The development of the questionnaire started with the conceptualisation process. This phase was followed by item generation and decisions about the variables involved (independent and dependent variables), that were made through discussions with experts. Four experts participated in the development phase as members of the research team, which included two public health physicians, an infant

feeding consultant, and a biostatistician. A member of the research team was the coordinator for all communication processes involved (Giesen *et al.*, 2012). Each item or question was discussed in detail to ensure that all respondents could understand it the same way. Vague contents, difficult or ambiguous terms, negative phrases, multiple ideas or concepts in one item, and leading or double-barrelled questions were avoided.

The Delphi technique is a structured group communication process that involves four phases: 1. Exploration of a subject by a group, 2. Reaching an understanding of how the group views the subject, 3. Resolving disagreements, and 4. Final evaluation (Linstone, Turoff & Helmer, 2002). However, a modified Delphi approach was implemented in this study because it allowed the research team members to interact in the final round to clarify issues and present arguments justifying their viewpoints (Eubank *et al.*, 2016). The development process consisted of five phases, namely: 1. Identification of domains, 2. Verification of identified domains, 3. Identification of relevant and representative items, 4. Definition of the domains, and 5. Final verification of the domains and items.

Identification of domains in IYCF

An extensive literature review on IYCF was conducted. Specifically, this systematic review focused on literature contents that were relevant for the development of the questionnaire, namely on breastfeeding and complementary feeding, the role of childcare providers, assessments of KAP, existing questionnaires, childcare services, and IYCF-friendly centres. Keywords used in database searches were “infant and young child feeding,” “childcare providers,” “breastfeeding,” “complementary feeding,” “KAP,” and “childcare centres.” The databases used included the Cochrane Library,

PubMed, Medline (Web science), Scopus, and Medline Ovid. Each member of the research team comprehensively reviewed a number of questionnaires, which differed widely in their domains, theoretical backgrounds, validation approaches, and the quality of the validation evidence. The research team (experts) also reviewed various locally and internationally published guidelines on IYCF and training guidelines for childcare providers. Relevant literature reviews on other quantitative and qualitative studies, as well as theoretical frameworks were used to incorporate more ideas into the development of the new questionnaire.

The following list of guidelines and references were used during questionnaire development:

1. *Modul Latihan Pemakanan Bayi dan Kanak-Kanak* [Infant and Young Child Feeding Training Module] (MOH Malaysia, 2008)
2. *Modul Kursus Asuhan dan Didikan Awal Kanak-Kanak Permata Negara* [PERMATA Basic Child Care Module] (Aminah *et al.*, 2013)
3. *Panduan Pengendalian dan Pemberian Susu Yang Selamat di Pusat Jagaan dan Taska* [Guidelines on the Safety and Proper Handling of Infant Feeding in Childcare Centers] (MOH Malaysia, 2012),
4. Malaysian Dietary Guidelines for Children and Adolescents (MOH Malaysia, 2013),
5. WHO Guidelines on Infant and Young Child Feeding (WHO, 2001; WHO, 2003; WHO, 2005), and
6. Published articles (Clark *et al.*, 2008; Freedman & Alvarez, 2010; Ismail & Sulaiman, 2010; Lucas *et al.*, 2013; Asis *et al.*, 2016)

All members of the research team suggested possible domains based on their own experiences and review of the literature. Each suggested domain

was continuously appraised until all members agreed on the number of identified domains to focus on.

Verification of identified domains

A meeting was then held with the experts to verify the identified domains. To verify the domains, each domain was scrutinised for its appropriateness and applicability to childcare providers. Only domains related to IYCF that were verified by the experts as appropriate for and applicable to childcare providers were included.

Identification of relevant and representative items

Once the provisional definitions were clear enough to warrant item construction, an email was sent to the research team members (experts) asking them to contribute relevant and representative items for each domain. They were encouraged to contribute as many items as possible, including positively and negatively worded items. These contributed items were then discussed in meetings.

Definition of the domains

Definitions for the verified domains were agreed on by the research team members. They continuously improved the definitions and critically appraised alternative definitions based on literature reviews and expert opinions, while keeping all definitions within the context of assessing childcare providers' KAP on IYCF. Discussions were continued via e-mail and face-to-face meetings until all research team members (experts) agreed on the provisional definitions for each of the domains.

Final verification of domains and items

A final meeting was held with all the original research team members (experts) and one additional expert who was not involved in the earlier four

initial phases. The domains, definitions, and items were again appraised by the new expert. Response options to these items were also chosen in this meeting, and the advantages and disadvantages of different response formats were considered. The content-validated questionnaire (Draft 1), which has appropriate and relevant content to its construction, was produced during this phase.

Formatting and layout of the new questionnaire

Draft 1 of the questionnaire was then formatted by researchers to make it more presentable to the respondents for self-administration. For a self-administered questionnaire, formatting is an essential factor in respondents' motivation in taking time to complete the questionnaire. As a secondary benefit, careful formatting can reduce errors in the subsequent preparation and processing of data. Certain formatting conventions for text, response categories, and overall layout have been shown to enhance data quality and, as a result, are commonly used in questionnaire design (McDonald et al., 2003).

After content validation, the next step was a pre-survey evaluation to assess the response process. This was done through cognitive debriefing (intensive interviews), after which the questionnaire was pre-tested.

Cognitive debriefing

Cognitive debriefing is part of the response process. It is conducted by researchers to ensure that respondents understood a newly developed questionnaire (Farnik & Pierzchala, 2012). It functions as a qualitative assessment of the questionnaire. It assesses for any errors that may be introduced by interpretations of specific questions, inability to recall necessary information, or respondents' judgments that might

affect their answers. In this stage, items that may have been conceptually inappropriate were highlighted. The steps involved in cognitive debriefing, according to (Campanelli, 1997), are:

1. A comprehensive review of each item's intention and the meaning of terms,
2. Retrieval of relevant information and the respondent's view of input,
3. An assessment of the respondent's decision process and whether the respondent devoted sufficient mental effort to answering the questions accurately or were merely guessing,
4. An assessment of the respondent's process to determine whether the response options are clear and whether the respondent's desired options are included, and
5. General comments (e.g. the length of the questionnaire).

The other aim of cognitive debriefing was to identify difficult or confusing items. It was also used to assess whether the questionnaire could be improved. The research team also determined whether some respondents interpreted certain items differently. Alternative suggestions from respondents were recorded, and the questionnaire was amended accordingly. The cognitive debriefing was conducted using the think-aloud method and verbal probing techniques (McDonald *et al.*, 2003; Willis, 2005).

It is recommended that cognitive debriefing be conducted with at least ten participants, including experts and target respondents (Souza & Rojjanasrirat, 2011). In this study, cognitive debriefings were conducted with eight childcare providers from one registered childcare centre in the Kota Bharu district, one nutritionist from the Kelantan Health State Department, and one representative from a non-governmental organisation (NGO) who works with childcare providers and

childcare centres (PERASKO).

The results of the cognitive debriefings were reviewed so the findings from this process could be incorporated in the questionnaire. Respondents' interpretations of items were compared to the original version to identify and amend discrepancies. The results of the cognitive debriefing were discussed with the members of the research team. The members evaluated all the respondents' comments and suggestions, and the questionnaire was revised accordingly to produce Draft 2 of the questionnaire.

Pre-testing the questionnaire

Pre-testing is an assessment of the entire questionnaire, all procedures involved in its administration, and the preparation of its data for analysis. Pre-testing was conducted by researchers on a homogenous group of 30 respondents (McDonald *et al.*, 2003). The 30 pre-test participants were childcare providers from nine registered childcare centres in another district.

Draft 2 of the questionnaire (Table 1) was tested to determine the questionnaire's length, user-friendliness and overall flow (including transitions between sections), the level of respondent interest and attention, comprehension of the items, as well as the maximum time needed to respond to the questionnaire. In this study, all respondents answered all the questions within 45 minutes. The overall comments and level of respondent acceptance were good, and the testers provided positive feedback.

The pre-test results (Table 2) were reviewed and finalised to incorporate the findings of the pre-testing process into additional revisions of the questionnaire. Discrepancies in respondents' interpretations of items were identified. The results of the pre-test were explained and discussed with the members of the research team. The members evaluated all the respondents' comments and

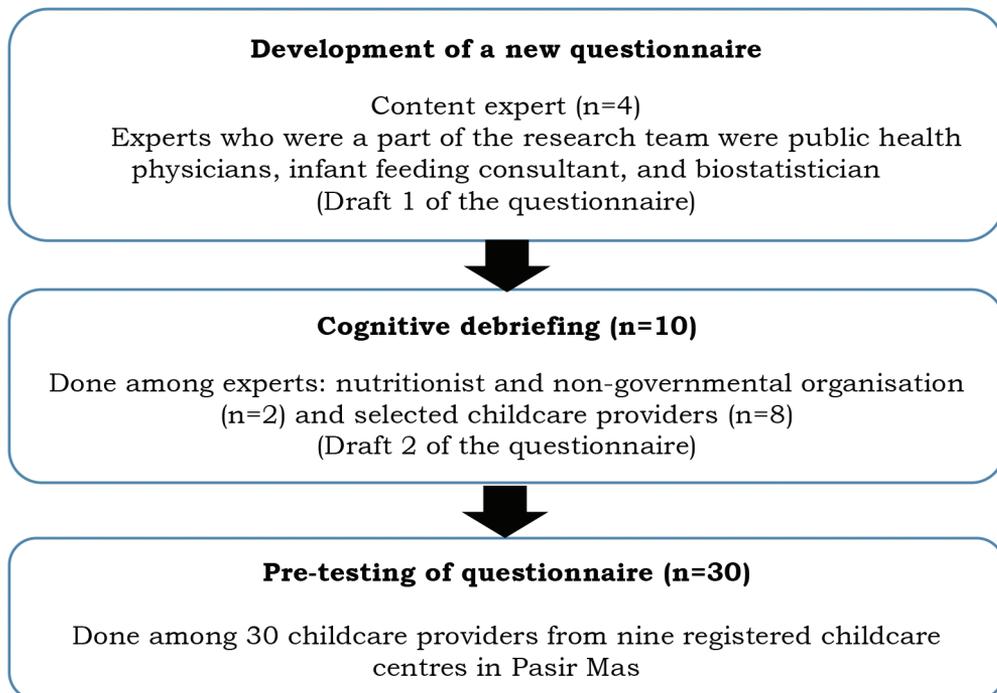
Table 1. Items in the Draft 2 questionnaire

<i>Components</i>	<i>Sections & no. of items</i>	<i>Concepts measured</i>	<i>Response options</i>
General information (37 items)	Five sections pertaining to individual and group level factor	<ol style="list-style-type: none"> Socio-demographic (age, gender, ethnicity, educational level, marital status, health status) Job characteristic [working experience (years), job scope, total number of care, total number of providers in a centre, workload] Workplace characteristic (YCF friendly facilities, operation time) Parental experience (past experience on IYCF: breastfeeding and complementary feeding, number of the child) Training [KAKP (basic childcare course), other training, frequency in getting information, another source of information] 	Closed-ended, multiple-choice
Knowledge (104 items)	Section A: breastfeeding and formula feeding (67 items (27 reverse-scored items))	Knowledge on the advantage to mother & infant, effective feeding, express breastmilk (EBM), the problem with breastfeeding, practical aspect of breastfeeding, formula feeding, preparation and handling of formula feeding.	True/False/Don't know; 1 = True 2 = False 3 = Don't know
	Section B: complementary feeding (37 items (20 reverse-scored items))	Knowledge on complementary feeding, advantage, appropriateness in implementation (practical aspect: preparation and handling), response feeding	
Attitude (90 items)	Section A: breastfeeding and formula feeding (40 items (12 reverse-scored items))	Measure three components towards breastfeeding and complementary feeding based on tri-partite theory (Tuckman, 1999). The following components as below: 1. Cognitive: belief, thought, attributes 2. Affective: emotion/feeling 3. Behavioural: past experiences	Five-Likert scale option 1 = Strongly disagree 2 = Disagree 3 = Not sure 4 = Agree 5 = Strongly agree
	Section B: complementary feeding (50 items (23 reverse-scored items))		
Practices (42 items)	Section A: Handling EBM (6 items: 1 negative statement)	Practices on IYCF practices: breastfeeding and complementary feeding	Four-Likert scale option 1 = Never 2 = Seldom 3 = Often 4 = Always
	Section B: Giving EBM (13 items: 3 negative statement)	Designed to be measured descriptively per item	
	Section C: Handling formula milk (8 items)		
	Section D. Handling feeding bottle (5 items)		
	Section E. Food Storage (5 items)		
	Section F. Responsive feeding (4 items: 1 negative statement)		

Table 2. Percentage of comment per item for draft 2 of the new questionnaire (n=30)

<i>Comment</i>	<i>Mean (SD)</i>	<i>n (%)</i>
The arrangement of sentences and meaning of the words		
Well understood		24 (80.0)
Difficult to understand certain sentences		5 (16.7)
Took some time to understand		1 (3.3)
Type of writing and font size		
Met the formatting		24 (80.0)
Easy to understand		3 (10.0)
Need to increase the font size		3 (10.0)
The arrangement of table and paragraph		
Well arranged		26 (86.7)
Neat and nice		4 (13.3)
Another comment		
Any suggestion		2 (6.7)
No suggestion		28 (93.3)
Requirement time to answer questionnaire (minutes)	45.5 (10.45)	

Questionnaire development flow chart

**Figure 1.** Flow chart on the development, cognitive debriefing and pre-testing of questionnaire

suggestions, and the questionnaire was revised accordingly to produce Draft 3.

RESULTS

Four experts were involved in the development phase, and ten respondents participated in cognitive debriefing. Pre-testing was conducted among 30 childcare providers from nine registered

childcare centres in Pasir Mas, Kelantan. Most of the childcare providers who participated were young with a mean age of 27 ± 9.89 years old, female (100.0%), Malay (100.0%), single (56.7%), healthy (93.3%), and had completed secondary education (86.7%). Most of them did not have children (56.7%), so they lacked personal experience with breastfeeding (Table 3).

Table 3. Sociodemographic characteristic of child care providers in Pasir Mas ($n = 30$)

<i>Variables</i>	<i>Mean (SD)</i>	<i>n (%)</i>
Age (year)	27 (9.89)	
Gender		
Female		30 (100.0)
Ethnicity		
Malay		30 (100.0)
Education level		
Lower than Diploma		26 (86.7)
Diploma or higher		4 (13.3)
Marital status		
Married		13 (43.3)
Single		17 (56.7)
Health status		
No comorbidity		28 (93.3)
Had comorbidity		2 (6.7)
Employment		
Total working experience (years)	2.2 (4.00) [‡]	
Experience in the current centre (years)	2.1 (4.40) [‡]	
Total working hours per day	9.2 (1.52)	
Workload		
Total children in centre	18.0 (9.39)	
Total children cared per provider	9.0 (8.84)	
Total provider per centre	3.9 (1.56)	
Employment scope [†]		
Care of child <2 years old		23 (76.7)
Care of child >2 years old		25 (83.3)
Serve food		23 (76.7)
Monitor child during eating		21 (70.0)
Other scopes		4 (13.3)
Duration of centre operation per day (hours)	10.8 (0.66)	
Centre having overtime service		19 (63.3)
Involvement with overtime service		14(46.7)
Self-experience		
Had own-child		8 (26.7)
Total children ($n=8$)	0.7 (1.37)	
Breastfeeding experience		9 (30.0)
Maximum breastfeeding duration ($n=9$)	5.3 (10.57)	
Exclusive breast feeding (yes)		1(3.3)
Age of starting complementary food ($n=8$) (month)	1.5 (2.58)	

Table 3. Sociodemographic characteristic of child care providers in Pasir Mas (*n* =30) (continued)

<i>Variables</i>	<i>Mean (SD)</i>	<i>n (%)</i>
Facilities at childcare centres [†]		
Consent for mother nursing their infant		22 (73.3)
Breastfeeding corner		16 (53.3)
Refrigerator for EBM		28 (93.3)
Breast pump		1 (3.3)
Educational material		22 (73.3)
Training		
KAKP course (involvement)		20 (66.7)
Last training (years) (<i>n</i> =20)	2.2 (2.38)	
Other relevant course		18 (60.0)
Information system		
Own initiative to search for information		19 (63.3)
The frequency of searching information (per month)	1.4 (1.74)	
Information system		
Source [‡]		
Internet		16 (53.3)
Books		11 (36.7)
Pamphlet		10 (33.3)
Magazines		12 (40.0)
Support group		2 (6.7)
Health care provider		8 (26.7)
NGOs		0 (0.0)
Others		0 (0.0)
Information source category		
No source		11 (36.7)
At least one source information		5 (16.7)
More than one source information		14 (46.7)

[†]Respondents may answer more than one options

[‡]Median (IQR)

During the development process, a total of 233 items were generated for the questionnaire. It consisted of two main components: component A (pro forma, general information) and component B (addressing the three major domains on knowledge, attitudes and practices regarding IYCF). The two sections (A and B) addressed knowledge and attitude: section A covered breastfeeding and formula feeding, and section B addressed complementary feeding.

The section on knowledge of breastfeeding and formula feeding covered the advantages of breastfeeding to mothers and infants, the effective implementation of breastfeeding,

breastmilk expression, breastfeeding problems, and practical aspects of breastfeeding, formula feeding, and the preparation and handling of formula. The section on knowledge of complementary feeding addressed the advantages of complementary feeding, implementation of complementary feeding (including preparation and handling), and the concept of responsive feeding.

The items on attitude were based on the tripartite theory of attitude (Lawrence, 2008). According to this theory, attitude includes cognitive, affective, and behavioural components. The practice domain included six activities: handling expressed breastmilk, feeding

expressed breastmilk, handling formula, handling bottles, food storage, and responsive feeding. These sections assessed respondents' knowledge on the practical handling of breastfeeding and complementary feeding.

All the domains were defined in the context of IYCF and childcare provider settings. Appropriate Likert scales were designed for the response options in each section (Table 1). Items in the knowledge section had response options of "true," "false," and "don't know." Reverse scoring was used for negatively worded items. One point was given for a correct answer and zero points for an incorrect answer or a response of "don't know." The possible score for this section ranged from 0 to 67 for section A, and 0 to 37 for section B. Each participant's total knowledge score was calculated and then converted to a percentage score by dividing it with the maximum score and multiplying the result by 100. A higher percentage score on knowledge indicated more knowledge of the item tested.

The items on attitude had response choices of a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Points were assigned in ascending order as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree. Even-numbered items were positive statements and for these, the Likert scale number was also the item's contribution to the score. For odd-numbered items (the negative statements), the score contribution was 6 minus the Likert score. The score could range from 40 to 200 for section A, and 50 to 250 for section B. The practice section consisted of 42 questions rated on a four-point Likert scale. Points were given in ascending order as follows: 1 = never, 2 = seldom, 3 = sometimes, and 4 = always. Each item in the practice domain of the questionnaire was described individually.

During cognitive debriefing, six new items were added to the questionnaire and three items were dropped. Several items were rephrased or revised. As a result, a total of 236 items in Draft 2 of the questionnaire were retained for pre-testing. In pre-testing, the overall comments and acceptance of the questionnaire were good, although participants needed a lot of time to answer all the questions. The mean (standard deviation, *SD*) time required for respondents to complete the questionnaire was 45(10.45) minutes. Other findings are summarised in Table 2. The questionnaire was revised again based on the results of the pre-testing phase, and 236 items (knowledge: 104 items; attitude: 90 items; practice: 42 items) remained, as in Draft 2 of the questionnaire, for the assessment of internal structural validity as items met the criteria for clarity (Table 1).

The resulting new questionnaire was named the IYCF-CCPQ, which stands for Infant and Young Child Feeding Questionnaire for Childcare Provider or '*Borang Kaji Selidik Pemakanan Bayi dan Kanak-kanak dalam kalangan Pengasuh*'. This new questionnaire can potentially be used to assess respondents who are related to the nature of childcare, such as childcare providers, care givers, and parents especially mothers.

DISCUSSION

The aim of this study was to develop a new questionnaire on IYCF to assess the KAP of childcare providers in registered childcare centres in Kelantan. A modified Delphi technique was used to develop a new questionnaire, the IYCF-CCPQ, which is culturally appropriate for use in Malaysia, especially among the Malay ethnic group.

The questionnaire met the predefined goals. Firstly, the questionnaire was developed specifically for childcare

providers, which was reflected in its specific content to the context of work among childcare providers. Secondly, Likert scales were used for the responses to simplify the questionnaire's administration and make it suitable for factor analyses. Likert scales have also been used in other studies (Freedman & Alvarez, 2010; Abdul Ghani *et al.*, 2016; Zahiruddin *et al.*, 2018). Thirdly, the questionnaire was based on the application of the tripartite theory of attitude to IYCF (Pickens, 2005; Lawrence, 2008).

Particular attention was paid to the adequacy of the questionnaire's content, specifically in terms of the number and scope of individual statements and whether they were representative, consistent, and relevant to the context. These issues were considered throughout the development process by the research team members who acted as experts (McDonald *et al.*, 2003; Giesen *et al.*, 2012). In this study, public health physicians, an infant feeding consultant, and a biostatistician brought their expertise to review the concept and content of the designated tool. The item scoring methods were also reviewed by experts, such as the biostatistician. According to Rattray and Jones (2007), content validity can be measured by expert opinions on whether the items and scales represent the domains or concepts that the tool is intended to assess.

Face validity can also provide a superficial understanding of how target respondents might understand and respond to the questions (McDonald *et al.*, 2003). Respondent feedback in cognitive debriefing and pre-testing helped improve the comprehensibility, layout and presentation, as well as the estimated time needed to administer the IYCF-CCPQ. The readability and ambiguity of structures, passages, sentences, answer options, and

instructions were also assessed. Readability is particularly important in a self-administered questionnaire and ensures that the questionnaire can be understood by most of the target population, which will increase its response rate. The readability of the IYCF-CCPQ was observed during cognitive debriefing and pre-testing, during which respondents were asked about the readability of the pre-validated IYCF-CCPQ. All respondents stated that they were able to fully understand the pre-final IYCF-CCPQ.

Cognitive debriefing and pre-testing were also among the methods used to determine the IYCF-CCPQ's operational equivalence. In this study, operational equivalence referred to the use of a similar layout, instructions, mode of administration, and measurement method to those of another questionnaire. The IYCF-CCPQ was administered in a similar way to other questionnaires from previous studies (Freedman & Alvarez, 2010; Lucas *et al.*, 2013; Che' Muda *et al.*, 2018). Self-administration has several advantages: it uses fewer resources than interviews, and is easy and convenient for respondents.

During pre-testing, the overall comments were good, although it took participants some time to answer all the questions. All respondents were motivated to complete the questionnaire. A possible explanation for this might be the questionnaire's standardised format and clear layout, its easily understandable content, and the fact that it was a newly developed comprehensive questionnaire on IYCF. These factors meant that participants were willing to answer all the questions even though it took them 45 minutes. The respondents' answers were symmetrical, and all of the response options were used. This indicated that the choice of responses effectively measured the childcare providers' KAP regarding IYCF.

We were able to produce a good and comprehensive questionnaire that covered the whole aspect of IYCF, focusing on childcare providers. However, our limitation was the length of the questionnaire. We strongly recommend for future researchers to use this comprehensive and long version of IYCF-CCPQ as a baseline tool to develop a shorter and more brief version of IYCF-CCPQ, by separating the sub-sections of breastfeeding and complementary feeding as deemed necessary. With the short and brief version of IYCF-CCPQ, it will help researchers to do comparable studies to assess the validity of these tools. The online version of IYCF-CPQ can also be developed in order to conduct a massive survey regarding infant feeding practices among childcare providers at the national level.

CONCLUSION

The IYCF-CCPQ is a new questionnaire designed to measure childcare providers' KAP regarding IYCF. In its present form, the questionnaire addresses three domains - knowledge, attitudes and practices, and contains 236 items rated on a Likert scale. Before the IYCF-CCPQ is used, a proper validation study should be conducted to determine its psychometric properties.

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Authors' contributions

NMZ, principal investigator, conceptualised and designed the study, prepared the draft of the manuscript and reviewed the manuscript, led the data collection in the Northern east region, conducted the study, data analysis and interpretation; TATI, advised on the design and conduct of the study, and reviewed the manuscript; WNAWM, advised on the data analysis and interpretation and reviewed the manuscript; ZS, reviewed the manuscript; TFTH, advised on data collection and reviewed the manuscript.

Conflict of interest

The authors declare that they have no conflicts of interest regarding this study.

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Determination of glycaemic response of a novel cane sugar product incorporated with *Phyllanthus emblica* and *Zingiber officinale* extracts

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ABSTRACT

Introduction: The use of natural plant extracts to reduce blood glucose response has been practised from ancient times, although their industrial applications are rare. For the convenience of typical cane sugar consumers, selected tropical plant extracts were incorporated with cane sugar to make a low glycaemic sugar product.

Methods: This study compared the glycaemic responses of a commercially available product (Product 1) containing seven herbal extracts; fenugreek (*Trigonella foenum-graecum*), turmeric (*Curcuma longa*), black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), cinnamon (*Cinnamomum verum*), gooseberry (*Phyllanthus emblica*) and pomegranate (*Punica granatum*) against a novel product (Product 2) that was made by incorporating only two plant extracts that were cheaper and readily available in the local market - gooseberry (*Phyllanthus emblica*) and ginger (*Zingiber officinale*). Extracts were incorporated with cane sugar to make a series of crystallised solid sugar products and the formulae with the best sensory attributes was selected (Product 2). The glycaemic indices of both products were determined by standardised methodology using 12 healthy volunteers in a randomised crossover study. **Results:** The mean glycaemic index (GI) value for sugar in Product 1 was 49±9 and in Product 2 was 38±9. Both results elicited significantly ($p<0.05$) lower GI values than normal cane sugar (GI=65). The novel cane sugar product (Product 2) was far more superior compared to the commercially available product (Product 1) in reducing blood glucose response. **Conclusion:** Incorporation of suitable herbal extracts to cane sugar and foods like rice and wheat flour may be a suitable option to reduce their glycaemic impact.

Keywords: Cane sugar, diabetes, ginger, glycaemic index, gooseberry

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INTRODUCTION

Diabetes mellitus is very common among ageing people and two thirds of the global diabetic population are living in developing countries. Among them, Sri Lanka is one of the countries in the world that has a high diabetes prevalence rate (Katulanda, Sheriff & Matthews, 2009). Diabetes is the hyperglycaemic condition caused as a result of defects in insulin secretion, insulin action or both, and is considered as a metabolic disorder (Goldenberg & Punthakee, 2013). In a healthy adult, blood glucose level is managed primarily by insulin, which converts glucose into energy to function the activities of the body. However, people with diabetes no longer produce insulin or do not produce sufficient amount of it to convert blood glucose into energy (Kharroubi & Darwish, 2015; Röder *et al.*, 2016).

Among the nutrients, carbohydrate is the most important nutrient that contributes to the conversion of glucose into energy. Therefore, it is advisable that diabetic patients select low glycaemic index (GI) carbohydrates to avoid the release of high quantities of glucose into the blood (Eleazu, 2016).

Although a change in diet and exercise can help manage diabetes, most patients in Sri Lanka ultimately require oral anti-diabetic drugs to manage the disease (Kumara & Siriwardena, 2016; Valitutto, 2008). This may be due to the high consumption of cane sugar incorporated foods. According to Wrolstad (2011), consumer food items such as biscuits, cakes, chewing gums, carbonated beverages, ready to serve drinks, jams and spreads are rich in sugar. Sugars are used in these items mainly as sweeteners, as well as to improve their palatability and as a preservative. Hence, formulation and consumption of low glycaemic impact sugar products has been a topic of

interest for many years.

A variety of traditional herbs, spices or their mixers used in Sri Lanka have beneficial effects on diabetes and they are non-prescription treatments for diabetes. However, their efficacy has yet to be investigated. Here, we incorporated herbal extracts to cane sugar with an aim to suppress its glycaemic impact.

In this study, only two edible plant sources were selected - gooseberry (*Phyllanthus emblica*) and ginger (*Zingiber officinale*), for the formulation of a novel product, considering their higher efficacy in traditional diet therapies, as well as their cost effectiveness; enabling these products to be made at the commercial level with a lower price. These plant sources are highly rated for their health benefits in Ayurvedic medicine and are popular among communities in South and South-East Asia as “nutritive” plant foods. The incorporation of such active food ingredients can readily induce the activity level of insulin and its sensitivity in cells, as shown by a previous study (Gunathilaka & Ranaweera, 2018).

Gooseberry (*Phyllanthus emblica*) is popular for its high vitamin C content, which stimulates the pancreas and enables it to secrete insulin, thus reducing blood sugar level (Patel & Goyal, 2011). It also prevents aggregation and insolubilisation of lens proteins (development of secondary complications of diabetes, including cataract) caused by hyperglycaemia (Daisy, Averal & Modilal, 2005; Suryanarayan *et al.*, 2007). The tannoids and tannins of *Phyllanthus emblica* are potent inhibitors of aldose reductase (AR), thus making them potential drugs for non-insulin dependent diabetics by enhancing glucose uptake and inhibiting adipogenesis (Modak *et al.*, 2007). In addition, the presence of antioxidants neutralises free radicals, which is effective in preventing, as well as reducing

the severity of diabetic complications (Modak *et al.*, 2007). Further researches by Akhtar *et al.* (2011) and Shah *et al.* (2005) concluded that gooseberry as a supplement, is effective in reducing fasting and post-prandial blood glucose levels and glycated haemoglobin (HbA1c) levels.

Ginger (*Zingiber officinale*) is abundant with gingerol, shogaols, zingerone and paradol, which are all potent bioactive compounds (Choudhari & Kareppa, 2013). A study suggested that ginger has a therapeutic benefit in lowering fasting serum glucose level in Type 2 diabetes patients (Andallu, Radhika & Suryakantham, 2003). Although it remains uncertain which bioactive compound in ginger is causing this anti-diabetic efficacy, it is likely that its predominant pungent compound, 6-gingerole, is responsible for this (Choudhari & Kareppa, 2013).

The synergistic effect of these two plant sources on diabetics has yet to be investigated. Thus, the current work aims to understand the synergy of gooseberry and ginger on glycaemic responses and to determine whether tropical plant food extracts can be incorporated into sugar to lower its glycaemic impact, while providing the best sensory attributes. Findings of this study will be useful in producing sugar substitutes which would have minimal impact in elevating blood glucose level.

MATERIALS AND METHODS

Chemicals list

Glucose oxidase-peroxidase kit (Biolabo, France), ethanol (BDH Anala R VWR International Ltd. Poole, England EC Label: 200-578-6), D(+)-Glucose (BDH Anala R VWR International Ltd, Poole, BH 15 1TD, England), sodium fluoride standard solution (Vishna chemicals, India).

Ethical clearance

Ethical clearance was obtained from the ethical review committee of the Faculty of Medicine, University of Sri Jayewardenepura, Sri Lanka under the reference no: 21/18.

Preparation of the sugar products

Product 1- Commercially available product

The commercialised sugar product, DiaBliss Herbal Sugar (DHS) is formed by Diabliss Consumer Products Pvt Ltd, incorporating seven herbal extracts, namely fenugreek (*Trigonella foenum-graecum*), turmeric (*Curcuma longa*), black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), cinnamon (*Cinnamomum verum*), gooseberry (*Phyllanthus emblica*) and pomegranate (*Punica granatum*) (Chockaligam *et al.*, 2018).

Product 2- Novel sugar product

Indian gooseberry (*Phyllanthus emblica*) fruits and ginger (*Zingiber officinale*) rhizomes were ground with minimum amount of water (200g:125ml) and extracts were filtered using 20-25 μ m (No.4 Watman) filter papers to get filtrates. Then a series of cane sugar concentration solutions with different brix values were made ranging from brix 16^o to 18^o (Table 1).

These solutions were heated to 115 $^{\circ}$ C and allowed to cool down while stirring well. At 100 $^{\circ}$ C and 90 $^{\circ}$ C, gooseberry and ginger extracts were mixed respectively in a particular ratio (Table 1). Mixtures were cooled down further and the final crystallised sugar was dried for three hours at 50 $^{\circ}$ C.

Sample size determination for sensory evaluation and for intervention

According to BS ISO13299:2003, descriptive panels may have '8-12

Table 1. Initial brix values and herbal extract ratios

<i>Trial sample number</i>	<i>Initial brix value</i>	<i>Herbal extract ratio (Gooseberry:Ginger)</i>
1	16 ^o	2:2
2	16 ^o	4:2
3	16 ^o	6:2
4	16 ^o	8:2
5	17 ^o	2:2
6	17 ^o	4:2
7	17 ^o	6:2
8	17 ^o	8:2
9	18 ^o	2:2

assessors' or more. They can either have as few as four (in consensus profiling) or as many as 20 to 30 when the purpose is to test for taints, to which only a minority may be sensitive. Therefore, this sensory evaluation was carried out by a semi-trained panel [discriminative and communicative (D&C) panel] of 30 individuals.

Sample size for the intervention should be a minimum of nine with a margin of error of six units for continuous outcome $n = (Z_{\alpha}/E)^2$ (Sullivan, 2019; Röhrig et al., 2010).

Recruitment of panelists for sensory evaluation

When selecting for panelists, criteria that were considered included interest and motivation, ability to memorise and communicate sensory impressions, availability for panel sessions, capacity to concentrate and honesty in reporting sensations, promptness, good health, ability to discriminate the specific characteristics studied and engagement for the duration of the study (BS ISO13299:2003) (ISO, 2003). Furthermore, we made sure we did not take respondents suffering from diseases such as colds, diabetes, mouth cancers, as well as those with addictions towards smoking, alcoholic beverages, chewing beetles et cetera. Finally, the panelists

should not have been exposed to any drug courses for a long time.

Sensory analysis

A sensory analysis was done for sensory parameters – appearance, odour, colour, taste and overall acceptability, with respect to six different chosen trial samples (Table 2) from the above (Table 1). The chosen trial samples were presented in the forms of:

- A. Dry crystals (trial sugar samples in dry crystallised form were served in comparison to normal cane sugar)
- B. Aqueous solution (2g of normal cane sugar and test sugar samples were dissolved in 250ml of water)
- C. Tea solution (2g of normal cane sugar and test sugar samples were dissolved in 250ml of tea solution)

Selection of the best sample

Successfully crystallised trial samples from the preparation (Table 1) were subjected to sensory evaluation. The best trial sample selected from the sensory analysis (Table 2) was recognised as the most suitable to be commercialised and used for further GI determination.

The commercial product (Product 1) already has a two-year shelf life and is certified with ISO22000. Microbiological tests were carried out to check whether the novel sugar product complied with

Table 2. Initial brix values and herbal extract ratios of chosen trial samples for sensory analysis (x- Trial component)

Trial sample number	Initial brix value & herbal extract ratio (Gooseberry:Ginger)	Presented form		
		Dry crystalised form	Aqueous solution	With tea
1	16 ^o 2:2	X	X	X
2	16 ^o 4:2	X	X	X
3	16 ^o 6:2	X	X	X
4	16 ^o 8:2	X	X	X
5	17 ^o 4:2	X	X	X
6	17 ^o 8:2	X	X	X

the Principles for the Establishment and Application of Microbiological Criteria for Foods, CAC/GL 21-1997 (CAC, 1997), Codex Standard for Sugar, CODEX STAN 212-1999 (CAC, 1999).

Intervention

Selection of study subjects for intervention
Healthy adults aged 20–45 years old with a body mass index (BMI) of 18.5–23.5kg/m², normal fasting blood glucose level (overnight fast of 8-12 hours) and who wished to voluntarily participate in this experiment were selected. Subjects without recent past history of chronic diseases and without present medical complaints were selected while maintaining gender balance (six males and six females). If the selected volunteer was pregnant, breastfeeding, intolerant or allergic to any of the foods, had problems such as consuming reference or test food samples, abnormalities in blood glucose responses or was not interested to give blood due to time limitation because of his/her lifestyle, then the volunteer was not considered for the study.

Feeding of the test food

According to the World Health Organization/Food and Agriculture Organization of the United Nations recommendations (FAO/WHO, 1998), there is a designated method used for measuring GI. Subjects were asked to report each testing session after an 8-12 hours overnight fast, to avoid cycling or walking to the laboratory and to not consume unusually large meals, drink alcohol or exercise vigorously on the previous day. In the first two sessions, subjects were given the standard reference food of glucose (D(+)-Glucose). In the next sessions, tested sugar products were given to them (each item was given twice), and they were requested to consume the foods within 15 minutes.

The amount of sugar and glucose per solution was determined according to the digestible carbohydrate content of the relevant materials and solutions that were made out of them, each containing 300ml. Solutions were prepared so that each of them contained 50g of digestible carbohydrates. Calculation for 50g of

available carbohydrate content is as follow:

Required amount (g) =

$$\frac{50}{(100 - M) \times X}$$

M: % Moisture content

X: % Available carbohydrate content

Blood collection

This intervention/human study was carried out particularly under the supervision of a medical doctor, a biochemist and a well-trained technical officer. Surface of the blood drawing environment was cleaned with ethanol and only sterilised needles were used for drawing blood. Each time when blood had to be drawn, the finger tips of participants were cleaned with ethyl alcohol before and after pricking.

Finger prick blood samples were obtained at 15–30 minutes intervals over the next two hours after the meal (at times 0, 15, 30, 45, 60, 90, 120 minutes; the beginning of the food intake was time 0). Samples were centrifuged at 7000rpm for ten minutes, and the serum was separated and was kept in refrigerated conditions until analysis.

Biochemical analysis

Concentrations of the blood glucose samples collected were determined by colorimetric method using glucose oxidase-peroxidase enzyme; with the use of Pap fluid glucose oxidase kit (Biolabo-France). Serum (10 μ L) was transferred to a clean, dry test tube with addition of the reagent (1mL), followed by incubation in a water bath (37°C, 10 minutes). Two replicates of each serum sample were used. Absorbance values for all samples were measured against a reagent blank, using Systronic spectrophotometer (modal: UVmini-1240, Serial No-A10934703413 CD, Japan).

The GI of the products were calculated according to the method of Jenkins *et*

al. (1981). The values of serum glucose concentrations were plotted against time at time 0, after 30, 60 and 120 minutes intervals after consumption of the reference food and test food for each individual. For each person, the incremental area under his/her blood glucose response [glucose incremental area under the curve (IAUC)] and for the tested sugar product (Product 1 or Product 2) was then measured by the trapezoidal rule (the sum of the surface of trapezoids between the blood glucose curve and horizontal baseline going parallel to x axis from the beginning of blood glucose curve at time 0 to the point at time 120 min to reflect the total rise in blood glucose concentration after consumption of a particular food).

Then, the individual's glucose IAUC for the test food was divided by his/her glucose IAUC for the reference food and the GI value for the test food was calculated for each person. The final GI value for each test food was the mean GI value of the 12 people for the respective product.

GI was calculated by the formula:

$$GI = \frac{\text{IAUC for the test food}}{\text{IAUC for the standard (Glucose)}} \times 100$$

(Brand-Miller JC, 2003; Jenkins *et al.*, 1981)

Statistical analysis

In sensory analysis, sugar samples were presented in the forms of dry crystals, aqueous solution and with tea. Hence, descriptive analysis were done for these three forms separately. The Friedman test, which is the non-parametric alternative to the one-way analysis of variance (ANOVA) with repeated measures was used since the test was for differences between groups when the dependent variable being measured is ordinal and for continuous data that has

violated the assumptions necessary to run the one-way ANOVA with repeated measures (e.g. data that has marked deviations from normality).

In GI calculations, IAUC of individual blood glucose responses were calculated by Microsoft Excel 2013. GI value and standard deviation values of each individual for each tested sugar product and for glucose were calculated using the same software at 95% confidence interval (CI). Comparison of GI values between commercial cane sugar and the two sugar substitute products was done using unpaired two tailed *t*-test (Microsoft Excel 2013) and *Q*-test was performed to identify existing outliers among the volunteers.

RESULTS AND DISCUSSION

Preparation of novel sugar product and sensory analysis

The initial sugar solutions were odourless and colourless at room temperature (29°C). When heating temperature of the solutions increased, thickness of the solutions increased too. At 115°C, *Phyllanthus* and *Zingiber* extracts were incorporated and solutions were allowed to cool down to solidify.

Solutions with higher initial brix values were solidified before adding ginger extract due to higher solid content. Solutions with lower initial brix values or higher herbal extract volumes were not solidified. According to the results observed, suitable initial brix values and herbal extract ratios were chosen for the sensory analysis (Table 2).

According to the microbiological test results, Product 2 (novel sugar product) was confirmed to be in accordance with the Principles for the Establishment and Application of Microbiological Criteria for Foods (CAC/GL 21-1997) and was therefore suitable for human

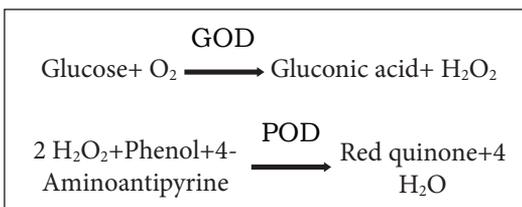
consumption.

According to the test results, there were no significant differences ($p>0.05$) observed (CI 95%) in the appearance, odour, colour and taste attributes between the six trial samples presented in aqueous solutions, with tea and in dry form; although it was demonstrated that (CI 95%) there was a significant difference between ($p<0.05$) the overall acceptability and considering sum of ranks. The best sample was chosen and used for the determination of GI.

Determination of glycaemic indices

From the initially selected 15 individuals, only 13 were finally selected into this study. From that group, one was released due to abnormalities in blood glucose responses. To maintain the gender balance in this study, six males and six females were selected.

Glucose oxidase method was the most suitable method to determine blood glucose concentration accurately. Glucose oxidase (GOD) converted the sample glucose into gluconate. The hydrogen peroxide (H_2O_2) produced in the reaction was degraded by peroxidase (POD) and gave a coloured product phenol and 4-aminoantipyrene, which was measurable using Trinder indicator reaction at 505nm. The increase in absorbance correlated with the glucose concentration of the sample (Bjorkhem *et al*, 1976).



If any red blood cells remained in the serum sample, it will absorb the glucose and may give false results. Interruption

with higher levels of red blood cells will not give a detectable value at all. After separation, serum sample must be adequate for carrying on further tests. Hence, immediately after collection, blood samples were centrifuged and serum was separated.

When GI values were expressed, the industrially made low GI sugar product demonstrated a GI value of 49 ± 9 and the GI value of the novel sugar product was 38 ± 9 . A significant difference ($p < 0.05$) was observed between the GI values of these two sugar products (Table 3).

The GI in Product 1 decreased from 65.0 to 49.9 (Table 3) with respect to normal cane sugar. When considering the novel product (Product 2), the decrease in GI was far greater; from 65.0 to 38.5 (Table 3). A significant ($p < 0.05$) decrease in the GI of both sugar products was observed compared to cane sugar.

Among the volunteers, 100% had elicited low GI values for both sugar products compared to normal cane sugar (Table 3). All 12 volunteers (six males and six females) were fed with both sugar products and 100% of them elicited low GI values for the

novel product (Product 2) compared to the commercially available Product 1 (Table 3).

The average percentage of GI reduction for Product 1 was $23.2 \pm 13.3\%$, while the novel sugar product (Product 2) showed a higher GI reduction of $40.8 \pm 13.7\%$ (Table 3).

When Q-test was used for the individual GI values of the volunteers, no outliers were found, confirming that all 12 data obtained for GI were valid. According to the statistical analysis, there were no significant differences observed in the mean GI values between males and females and across different age groups.

When the mode of peaking times is concerned, a much faster peaking time was visible in both sugar products and their peaking times shifted from 45 minutes to 30 minutes compared to the reference glucose (Table 4). With the observed values, there is a probability for peaking time to increase in both sugar products, within a larger sample. Both the commercialised low GI sugar product and the novel sugar product showed the same peaking time of 30 minutes.

Table 3. Individual Glycaemic indices and percentage GI reduction

Volunteer	Product 1		Product 2	
	GI for Product 1	% GI Reduction	GI for Product 2	% GI Reduction
1	45.4	30.1	36.8	43.4
2	37.8	41.8	33.4	48.7
3	52.5	19.3	17.8	72.7
4	45.1	30.7	45.0	30.8
5	58.2	10.5	43.7	32.7
6	56.6	13.0	41.1	36.7
7	56.7	12.7	32.0	50.7
8	67.3	-3.60	46.6	28.4
9	46.3	28.7	29.1	55.3
10	49.5	23.8	46.0	29.2
11	38.9	40.2	44.1	32.2
12	44.9	30.9	46.1	29.2
Mean	49.9	23.2	38.5	40.8
SD	8.6	13.3	8.9	13.7

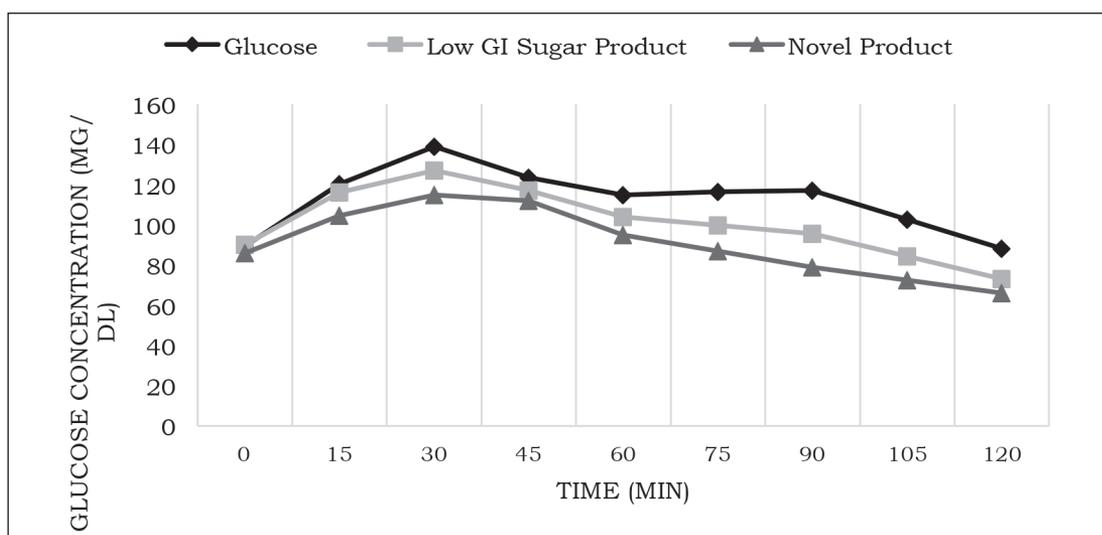
Table 4. Peak serum glucose concentrations and peaking times of individuals as observed in respective glucose response curves

Volunteer	Glucose		Product 1		Product 2	
	Time (min)	Concentration (mg/dL)	Time (min)	Concentration (mg/dL)	Time (min)	Concentration (mg/dL)
1	45	125	30	107	15	99
2	45	165	15	119	30	120
3	30	139	30	127	30	115
4	45	186	30	153	30	160
5	30	125	30	148	30	115
6	45	153	45	126	15	108
7	30	135	15	164	30	108
8	45	194	45	144	45	157
9	45	132	45	140	30	117
10	30	152	45	151	15	134
11	15	143	30	142	30	134
12	45	177	45	145	30	125
Mode	45		30		30	
Mean		152		139		124

The peak serum glucose concentration significantly decreased ($p>0.05$) from the reference glucose (152) to the commercialised low GI sugar product (139), and from the reference glucose (152) to the novel sugar product (124) (Table 4). This proves the effect of herbal extracts in decreasing immediate blood glucose response. Though the two sugar

products had similar peaking times, the peak serum glucose concentration in the novel sugar product (124) was lower than the commercialised low GI sugar product (139).

As for individual incremental area under the curve for sugar products, the maximum peaking time was similar (30 minutes) in both sugar products,

**Figure 1.** Incremental area under the curve for sugar products

as well as in cane sugar (Figure 1). Accordingly, the decrease in peak serum glucose concentration with respect to GI of the sugars was visible. The commercialised low GI sugar product (GI=49) had the highest peak in serum glucose concentration, while the novel sugar product (GI=38) had the lowest between the two sugar products. The peak reduction of the newly formulated product (Product 2) and its continued lowering of blood glucose levels was clearly visible during the two-hour period (Figure 1).

These incorporated herbal extracts contain a variety of active phytochemicals, including flavonoids, terpenoids, lignans, sulfides, polyphenolics, carotenoids, coumarins, saponins, plant sterols, curcumins, and phthalides. Due to the presence of bioactive compounds in them, several biological activities of these spices, such as antioxidants, anti-diabetes, anti-hyperlipidemic, or anti-hypertension, have been reported and validated (Susila *et al.*, 2017). Furthermore, these compounds are known to have a variety of health & wellness characteristics such as inhibiting cyclooxygenase enzymes, improving metabolism and enhancing insulin sensitivity, therefore can be the reasons for reduced GI values observed in these sugar products (Upasani *et al.*, 2013).

Although there was a significant difference in the average GI values of the two sugar products, the percentage in GI reduction of the novel sugar product was much lower (40.8%) compared to the 23.2% GI reduction observed in the commercialised low GI sugar product. Therefore, the difference in incorporated volume and raw materials of the herbal extracts (quantity and quality) should be the logical factor affecting this significant difference in the GI between these two products. There is still insufficient

evidence to draw definitive conclusions about the efficacy of individual herbs on glycaemic impact. However, they appear to be generally safe. Although both products contained gooseberry and ginger, the new product contained only these two, but in larger proportions. They have resulted in a better GI reduction, proving that gooseberry and ginger together have greater effects on reducing glycaemic impact than the rest of the five ingredients added in the commercial product.

According to the above study, the blood glucose response and peak serum concentration were relatively lower in cane sugar products incorporated with herbal extracts. Therefore, they are more suitable for consumption among people having issues related to diabetes and hyperglycaemia. Furthermore, encouraging the incorporation of suitable herbal extracts to foods like rice and wheat flour may be suitable options for individuals with the same health issues. Rather than using expensive raw materials, introducing substitute products using under-utilised native resources have several advantages, both from the financial and social perspectives.

CONCLUSION

The GI values of both sugar products incorporated with herbal extracts were significantly lower ($p < 0.05$) with respect to normal cane sugar, which was a decrease from the high GI category to the low GI food category. The GI of the novel sugar product (Product 2) was significantly lower ($p < 0.05$) than that of the commercially available product (Product 1). Hence, it is possible to conclude that *Phyllanthus emblica* and *Zingiber officinale* are superior in reducing blood glucose responses compared to many other known herbs.

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Authors' contributions

CHS, principal investigator, conceptualised and designed the study, led the development of the novel sugar product, conducted the study, data analysis and interpretation, prepared the draft of the manuscript and reviewed the manuscript; MAJ, advised on study design, assisted in developing the novel sugar product, data analysis and interpretation and reviewed the manuscript; SPASS, advised on study design and reviewed the manuscript; IW, assisted in developing the novel sugar product and reviewed the manuscript; BF, assisted in drafting of the manuscript, reviewed the manuscript; KKDSR, reviewed the manuscript; NHBW, assisted in data analysis and interpretation and reviewed the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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Effect of *Morus alba* (white mulberry) leaf on HbA1c of patients with type II diabetes mellitus

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ABSTRACT

Introduction: Diabetes mellitus is a wide spread metabolic disorder characterized by hyperglycemia. In Pakistan, many traditional or medicinal plants are being used to treat ailments or disorders, both in children and adults. To date, there has been no research study done to investigate the effect of *Morus alba* (white mulberry) leaves on blood glucose levels of individuals with type II diabetes mellitus in Pakistan. The present study was conducted to determine the effect of *Morus alba* (white mulberry) leaf powder on glycated haemoglobin (HbA1c) of patients with type II diabetes mellitus. **Methods:** The study design of this study was a randomised controlled trial. Eighty patients with type II diabetes mellitus were randomly selected from the Fatima Memorial Hospital and were equally divided into two groups - control group and experimental group. Patients in the control group were asked to follow their regular hypoglycaemic medications, while patients in the experimental group were administered with 500mg of *Morus alba* leaf tablet twice a day, 15 minutes before breakfast and dinner, along with their regular hypoglycaemic medications. HbA1c of patients in both groups were assessed on day zero before the study and on the ninetieth day at study completion. **Results:** HbA1c of patients in the control group at baseline was 8.92% and 8.91% at final, whereas HbA1c of patients in the experimental group at baseline was 9.13% and 8.59% at final. **Conclusion:** The results of this study concluded that *Morus alba* leaves had a significant effect in lowering high blood sugar levels.

Keywords: Deoxynojirimycin-1, diabetes mellitus, *Morus alba*, HbA1c

INTRODUCTION

Diabetes mellitus is a set of metabolic diseases characterised by hyperglycaemia. It is resultant of flaws in insulin secretion, insulin action, or both. Major clinical signs and symptoms of this disease are polyuria, polydipsia, weight loss, delayed wound healing and numbness in extremities. Subjects with glycated haemoglobin (haemoglobin A1c, HbA1c) of <5.7% have normal

blood glucose levels, while pre-diabetics have HbA1c of between 5.7% - 6.4% and diabetics have HbA1c >6.5% (ADA, 2018).

Many factors are responsible for the increase in the prevalence of diabetes mellitus among different regions of the world. Some factors are urbanisation, harmful eating practices and sedentary lifestyle. A study was conducted in the different provinces of Pakistan to

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investigate the prevalence of diabetes mellitus. The duration of the study was from April 2017 to November 2017. Subjects with factors that would affect HbA1c readings were excluded from the study. These factors included subjects with low haemoglobin (Hb) levels, with renal and liver disorders, had recently done blood transfusion, used erythropoietin and aged above 20 years. Investigators in the said study had used the American Diabetic Association's criteria for HbA1c. Their results concluded that in Pakistan, 16.98% were diabetics and 10.91% were pre-diabetics (Aamir et al., 2019).

A metabolic disorder like diabetes mellitus is a worldwide, global and epidemic disease. It is caused by the decrease in insulin production or decreased uptake due to increased resistance of the cells. Rather than managing this disorder via allopathic medicines, other variables or mediums have been investigated or identified for its management. About 80% of the people residing in developing countries use medicinal plants for their prime health care and have more trust towards traditional or herbal medications. As western medications or allopathic medications are too costly, therefore traditional medical therapies are often more preferred. Many medicinal plants and traditional medical therapies are undeniably effective (Sarangzai, Ahmed & Laghari, 2013).

Chae et al. (2003) reported that in Pakistan, a number of medicinal plants are being used for curing and treating diseases. In the plant kingdom, there are many varieties and species of plants available in different regions that are testified for managing high blood glucose values. A research article reported that in India, about sixty five plants are present that work against diabetes mellitus. Among these, *Morus alba* is a plant that works for the prevention of this disorder

(Mukherjee et al., 2006). *Morus alba*, also known as *Morus Indica*, a white mulberry tree is being used for its medicinal properties to cure diabetes mellitus as it possesses an anti-diabetic effect. Functional compounds that are present in its leaves are 1-deoxynojirimycin (DNJ), gamma-aminobutyric acid (GABA) and flavonoids.

Other than *Morus alba* leaves, many anti-diabetic extracts, anti-diabetic leaves and anti-diabetic seeds have been investigated to lower high blood sugar levels. The extracts of *Psidium guajava* L., *Ficus bengalensis* L., *Aloe vera* Nill, *Momordica charantia* L., *Allium cepa* L. and *Cajanus cajan* have also been found to be helpful for diabetics. The leaves of *Zizyphus jujuba* Mill and *Dodonaea viscosa* L. have been suggested for people with diabetes. The seeds of *Trigonella foenum-graecum* L. and *Withania coagulens* L. have also been recommended to be consumed by diabetics (Ahmad et al., 2009).

Morus alba leaves had been used traditionally as anti-inflammatory and anti-hyperglycaemic agents (Yatsunami et al., 2003). Human-based studies showed that oral intakes of 0.8g and 1.2g *Morus alba* leaf powder significantly reduced elevated blood glucose levels (Kimura et al., 2007). The content of DNJ present in *Morus alba* leaf is 1.622 mg/g (Liu & Zhu, 2006). A review study was conducted to explore the plants or herbs with medicinal potentials, especially the ones which would have anti glycated properties. Among the many plants reviewed in this study, *Morus alba* leaves were jotted for its medicinal properties against hyperglycaemia. Leaves of this plant works against hyperglycaemia in such a way that they impede the formation of advanced glycation end products (AGEs). Untreated diabetes for long periods of time will ultimately enhance the production of AGEs in the body, which will further enhance the

formation of reactive oxygen species (ROS). ROS has a leading role in causing mutations among genetic structures. Therefore, the combined effects of AGEs and ROS among diabetics can cause a devastating impact. *Morus alba* leaves have a potential to stop the production of AGEs and along with this, they have antioxidants which stops ROS from being effective (Dil, Ranjkesh & Goodarzi, 2019).

Among all these compounds, the most significant components of *Morus alba* leaves are DNJ and polyhydroxylated alkaloids, which possess inhibitory power against the working of the carbohydrate metabolising enzyme, alpha glucosidase. This enzyme resides in the small intestine and is firstly concerned with the hydrolysis of disaccharides in the small intestine, and secondly with the absorption of glucose in the blood vessels, which progresses onwards to the increase in blood glucose levels. DNJ present in *Morus alba* leaf is a strong natural alpha glucosidase inhibitor that works as an opponent of this enzyme in the small intestine, whereby it slows down the action of alpha glucosidase and ultimately decreases the abrupt spike in blood glucose levels; a positive point for type II diabetics (Yatsunami *et al.*, 2003). Therefore, this is predicted to bring a favourable effect on the suppression of abnormally high blood glucose levels (Nakagawa *et al.*, 2007). Literature showed that DNJ content is higher in young *Morus alba* leaves that are present in the upper branches of the tree, compared to mature leaves. The content of DNJ among *Morus alba* leaf varies on the basis of region, position of the branch on the tree, soil situation, 24-hourly cycle and climate of the year (Thakur *et al.*, 2019).

The basic objective behind this study is that in Pakistan, there is no research study that has been conducted to describe the effect of *Morus alba*. Studies

had been conducted to investigate the functions of its fruits, but no focus had been laid on the consumption of its leaves. This plant is available worldwide, including in Pakistan, to serve humanity. Natural alpha glucosidase inhibitors present in its leaves is a miracle against elevated HbA1c levels. So this study helped to estimate the quantity of *Morus alba* that is required to manage elevated HbA1c levels.

MATERIALS AND METHODS

Study design and sampling

The study design of this study was an open label randomised controlled trial. An ethical review letter numbered FMH-06-2018-IRB-475-A was signed from the Institutional Review Board (IRB) of Fatima Memorial Hospital (FMH), Lahore to carry out the study. After getting the IRB letter from FMH, 105 subjects were selected for the study. Among them, 80 met the selection criteria i.e. type II diabetic male and female patients, aged up to 60 years, and taking oral hypoglycaemic medications were included in the study. The patients were then equally allocated to treatment groups using GraphPad.

Patients with type I diabetes, type II diabetes on insulin treatment, diabetic patients with chronic disorders and pregnant or lactating mothers were excluded from the study. CONSORT diagram is shown in Figure 1.

Informed written consent was taken from the subjects. After explaining to patients about the aims and objectives of the study, they were ensured of the confidentiality of information. After taking consent, randomisation was done using a systematic sampling technique. One group was allocated conventional treatment and the other group was considered as experimental group. They were then further channeled to the three phases of the study:

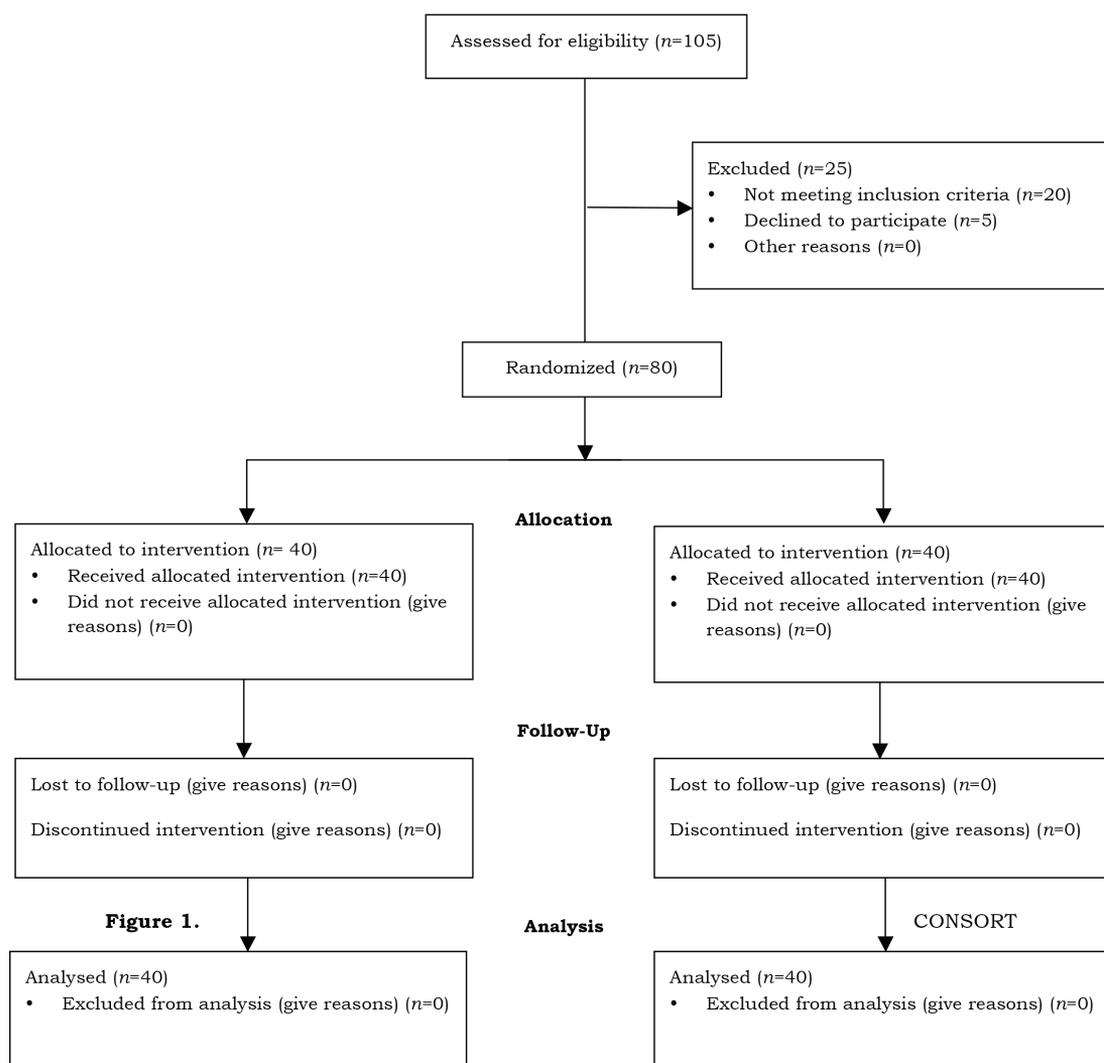


Figure 1. CONSORT diagram for enrollment of subjects

Phase I: Baseline assessment

At baseline, HbA1c levels of patients were assessed according to Bishop, Fody & Schoeff (2010).

Phase II: Intervention

The total targeted population was 80 adults with known type II diabetes mellitus taking oral hypoglycaemic drugs. The patients were randomly

allocated to treatment groups using GraphPad.

The hypoglycaemic medications of patients in both groups were not altered. Patients in the control group were asked to follow their regular regimens, whereas patients in the experimental group were asked to take 500mg of *Morus alba* leaf tablets twice a day with water, 15 minutes before breakfast and

dinner, for a total period of ninety days along with their regular medication. The formulation of the *Morus alba* leaf tablets was done according to the wet granulation method (Muazu, Abdulwoliyn & Mohammed, 2013). Substances used during the formulation of *Morus alba* leaf tablets were lactose monohydrate, corn starch, Avicel-200 and Kollidone K-30. Magnesium stearate was used for coating.

Phase III: Follow-up

After the interventional phase of ninety days, patients' HbA1c readings were measured.

Statistical analysis

Normality of data regarding HbA1c was checked using the Shapiro Wilk test for baseline ($p=0.056$) and for follow-up ($p=0.068$). As the data was normally distributed, independent sample *t*-test was applied for testing the difference between groups, while paired sample *t*-test was used to test for baseline and follow-up differences. A *p*-value of ≤ 0.05 was considered as statistically significant.

RESULTS

A total of 80 patients were included in the study and they were equally allocated to the experimental and control groups. The duration of diabetes in the experimental group was 5.90 ± 5.01 years and in the control group was 8.88 ± 5.26 years. The difference between these two groups was statistically significant ($p=0.011$), as shown in Table 1. *Morus alba* leaf tablets were uniformed for all the patients to prevent any sort of variation in results. Figure 2 shows the differences among HbA1c of patients in the control group and experimental group. Baseline measurement of HbA1c was taken at the start of the study and a final reading was taken on the ninetieth day.

Figure 2 shows that patients in the control group at baseline i.e. visit 1 had HbA1c of 8.92% and at final visit i.e. visit 2 had HbA1c of 8.91%. Results of patients in the experimental group treated with *Morus alba* leaf showed that at visit 1, their HbA1c reading before intervention was 9.13% and at visit 2 after intervention, HbA1c reading was 8.59%.

Table 1. Mean, standard deviation and *p*-value of age and duration of disease

	Experimental	Control	<i>p</i> -value [†]
Mean age of the patients (years)	53.70±9.76	53.25±8.79	0.829
Duration of disease (years)	5.90±5.01	8.88±5.26	0.011*

[†]Independent sample *t*-test

**p*-value significant at 0.05

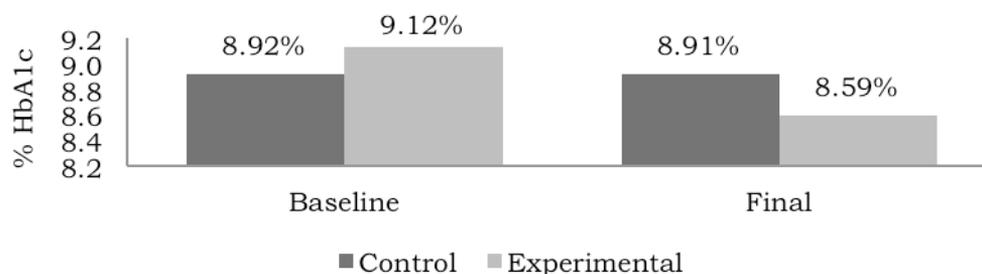


Figure 2. HbA1c of experimental and control group

Table 2. HbA1c of diabetic patients in control and experimental group

Group of patients	M±SD	p-value
Control group		0.559
Baseline	8.92±1.36	
Final	8.91±1.26	
Experimental group		0.001*
Baseline	9.13±1.33	
Final	8.59±1.31	

*p-value significant at 0.05

Table 2 shows the baseline values taken at the beginning of the study and final values taken at the end of the intervention. The results showed that at baseline, mean (*M*) and standard deviation (*SD*) for HbA1c value of patients in the control group was 8.92±1.36, and the final value was 8.91±1.26, where they were not statistically significant ($p=0.559$). *M* and *SD* at baseline for patients in the experimental group was 9.13±1.33, whereas the final value was 8.59±1.3 which was statistically significant ($p=0.001$).

DISCUSSION

The communal methods used for managing hyperglycaemia include inducing insulin or by ingesting hypoglycaemic medications. Many biochemical pathways have been studied to determine the effect of various compounds on hyperglycaemia. Among the investigated compounds, alpha glucosidase inhibitor is a very crucial one in regulating carbohydrate metabolism. This substance is available in the form of medicines and it is naturally available in white mulberry leaves (Ju & Kim, 2018). Other than this enzyme, white mulberry leaves are composed of proteins, dietary fibre and micro minerals. They provide anti-diabetic, anti-hypertensive, anti-pyretic and anti-inflammatory properties (Andallu & Vardacharyulu, 2001).

Insulin therapy provides only insulin and medical therapy only

provides specific compound, but white mulberry leaves provide a number of health protecting and health promoting compounds. Its leaves are known to provide anti-oxidative and anti-inflammatory properties to serve as free radical scavengers. So, on the basis of all these health benefits, white mulberry leaves can be used to manage hyperglycaemia. Because its constituent compounds will not only cope with high blood sugar level, but also protect an individual from any chronic disorders (Nazari et al., 2013).

Alpha glucosidase is an enzyme accountable for carbohydrate metabolism. When any carbohydrate-containing source is ingested, its activity starts and blood sugar level will begin to rise. Among diabetics, the control of this enzyme's activity is very worthy because the gradual increase in blood sugar level is a more stable condition. Hence, alpha glucosidase inhibitor is a compound that will slow down carbohydrate metabolism and therefore prevent the abrupt rise in blood sugar level (Ju & Kim, 2018).

A study was conducted on rats induced with diabetes to determine the effect of white mulberry leaf powder on blood glucose levels. The rats were divided into five groups; each group with six rats, and the total time period of this study was 60 days. Group one had normal control rats, group two had normal experimental rats treated with white mulberry leaf powder, group three

had diabetic controls, group four had diabetic experimental rats to be treated with white mulberry leaf powder and group five had diabetic experimental rats treated with hypoglycaemic medicines. Among these five groups; group one and group three were administered with the standard diet, while group two and group four were administered with an experimental diet incorporated with 25% level white mulberry leaf powder, and rats in group five received a normal diet along with hypoglycaemic medications. To produce mulberry leaf powder, its leaves were first collected and washed. They were then shade dried for a period of three days and lastly they were ground in an electric mixer to form a powder. Rats were tested for glycosylated haemoglobin and fasting blood glucose levels at first day and at sixtieth day. Results of this study concluded that fasting blood sugar levels among rats treated with mulberry leaf powder were significantly reduced by 50% when compared with diabetic rats in the control group, whereas there was only 28% reduction in blood glucose levels in rats treated with hypoglycaemic medications. HbA1c levels were significantly reduced by 30% ($p < 0.01$) among the rats treated with mulberry leaves, whereas HbA1c levels were decreased by 6% among rats treated with hypoglycaemic medications (Andallu & Vardacharyulu, 2001).

Another study was directed to determine the effect of mulberry leaves on diabetic rats. In this study, rats were given 10% mulberry leaves for a total time period of six weeks. At baseline, the rats were assessed for HbA1c and the final results showed that HbA1c values were significantly improved ($p < 0.05$) (Park *et al.*, 2012). Moran 20K and DNJ present in *Morus alba* leaves have a very affirmative influence on blood sugar levels of people with hyperglycaemia. Other than curing and maintaining blood sugar levels

among diabetics, *Morus alba* leaves, due to its neuroprotective properties, play an impactful role in preventing microvascular and macrovascular complications caused by hyperglycaemia (Butt *et al.*, 2008). During the study, the duration of diabetes seemed to be a contributing factor. In the experimental group, the *M* and *SD* for duration of disease was 5.90 ± 5.01 and in the control group, the *M* and *SD* for duration of disease was 8.88 ± 5.26 . Therefore, it is suggested that in future studies, the duration of diabetes should be controlled for to reduce cause and effect bias.

CONCLUSION

The study concluded that *Morus alba* leaves have a significant effect on hyperglycaemia. End results of the study showed that HbA1c levels of patients in the experimental group were statistically improved ($p = 0.001$), whereas the results of the control group were not significant ($p = 0.559$). Thus, by consuming *Morus alba* leaf tablets, high blood sugar levels can be normalised. However, the time and duration of consumption is very important. An ideal time for its consumption is 10-15 minutes before main meals. This study suggested that consumption of 500mg of *Morus alba* leaf tablets twice a day could help in the control of blood glucose levels among diabetic patients. It is also recommended that future studies be conducted to investigate the functions of all of its constituents and that studies must be conducted to focus on its form of administration i.e. tablet, powder or extract form.

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Authors' contribution

ZS, principal investigator hypothesised and set the aims of the study, organised the draft of the manuscript and reviewed the manuscript; NB, led the approval and arrangements of all the official credentials necessary for the study; SN, helped in the drafting and reviewing of the manuscript; AI, led the formulation of statistical methods and formulas; SAJ, led the interpretation of biochemical values obtained from subjects.

Conflict of Interest

The authors declare that there is no conflict of interest as the study was a self-sponsored project with no financial aid from any donor or organisation.

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Identification of dietary diversity associated with stunting in Indonesia

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ABSTRACT

Introduction: Stunting has become one of the world's most discussed health topics. Dietary diversity takes on an important role in increasing the nutrition fulfilment of young children aged 6–59 months for their optimal growth. This study aims to understand the association between dietary diversity and stunting in children aged 6–59 months old in Babakan Madang subdistrict, Bogor district of West Java, Indonesia. **Methods:** This study used a cross-sectional design and was conducted in May 2019 in Babakan Madang subdistrict. The subjects chosen for this study were 200 children aged 6–59 months, and they were selected using the probability-proportional-to-size sampling technique. Individual dietary diversity was assessed by minimum dietary diversity with the consumption of four or more food groups out of the total seven groups. Data were analysed using descriptive statistics and chi-square test. **Results:** Poor dietary diversity was significantly related with stunting ($p=0.023$; $OR=2.182$; 95% CI: 1.152–4.134). In addition, age <2 years was a significant protective factor against stunting ($p=0.011$; $OR=0.445$; 95% CI: 0.246–0.806). **Conclusion:** The risk of stunting in children can be reduced by providing a variety of foods in their diets, which includes at least four food groups a day. There is a need to increase awareness among the population about appropriate nutrition through dietary education.

Keywords: Stunting, dietary diversity, child nutrition

INTRODUCTION

Lost generation is a threat due to the increased incidence of stunting caused by suboptimal growth in children. Moreover, stunting is also linked with the risk of higher morbidity and mortality, as well as lower human development and productivity later in life (Prendergast & Humphrey, 2014). The Global Nutrition Report says that the world cannot afford not to act on nutrition: it is a critical linchpin for the global effort to end poverty and achieve sustainable development (Fanzo *et al.*,

2018). As a result, “stunting” has caught the attention of international nutrition and child health research, programmes, and policy circles (Perumal, Bassani & Roth, 2018).

In 2018, the worldwide statistics showed that just under one in four children (21.9%) aged <5 years has stunted growth (IFPRI, 2016). That said, overall trends are positive. The prevalence of stunting in young children in Indonesia was 30.8% in 2018. This prevalence is still much higher than the predetermined target

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of 28% envisaged in the Indonesia medium-term development plan 2019 (Kemenkes RI, 2018a). Meanwhile, the World Health Organization (WHO) targets a 40% reduction in the number of children under 5 who are stunted by 2025 (WHO/Antonio, 2014). Indonesia needs to make a serious effort to reduce its stunting problem in the country in order to circumvent the degraded quality of human capital that results from stunting (Paramashanti, Paratmanitya & Marsiswati, 2017).

Stunting is caused by two main causes - direct and indirect causes. The direct causes and aetiology of stunting include chronic inadequate diet (energy, macronutrients, and micronutrients) and infections (Frongillo, 1999). Quantity and quality of diet can be predicted by the diversity of foods consumed at the individual or household level to assess for nutrient adequacy (Krasevec, Kumapley & Frongillo, 2017). Toddlers should be given a variety of foods to support motor development and avoid mental disorders (Saaka, Osman & Hoeschle-Zeledon, 2017). Indirect causes such as age group, mother's parity, time of complementary feeding, age during pregnancy, and exclusive breastfeeding are also associated with stunting. The age group of <2 years is often considered to be associated with stunting. Mother's parity and age are also strongly associated with stunting in a child's first 5 years of life, particularly in post-stunting linear growth (Faye, Fonn & Levin, 2019). Furthermore, exclusive breastfeeding and complementary food should also be considered (Zhou *et al.*, 2012).

Although children <5 years should be introduced to dietary diversity (Rah *et al.*, 2010), in developing countries, including Indonesia, food intake is still primarily dominated by calorie-source foods and deficient in animal food sources, fruits and vegetables (Masibo

& Ochola, 2014). Food diversity in children, measured by individual dietary diversity score (IDDS), can be used as a predictor of stunting (Saaka *et al.*, 2017). According to previous studies, dietary diversity is related to the incidence of stunting, but other studies did not find the same results. Therefore, this study aims to address the association between dietary diversity and stunting in children aged 6–59 months.

MATERIALS AND METHODS

This study used a cross-sectional design. It was conducted in May 2019 in Babakan Madang subdistrict, Bogor district, West Java, Indonesia. The sample was 200 young children aged 6–59 months who were residents of Babakan Madang subdistrict. They were selected using the probability-proportional-to-size sampling technique where the Posyandu or Integrated Healthcare Center was used as cluster. The selected subjects were those who have signed an informed consent before data were collected.

Stunting was defined as an anthropometric status of length-for-age z-score of <-2 SD in children (Kemenkes RI, 2018b). Variables such as mother's parity, age group, time of complementary feeding, exclusive breastfeeding, mother's age during pregnancy, and child's history of infections were collected through interviews using a structured questionnaire. The questionnaire was tested beforehand for its validity and reliability. This study was approved by the Ethical Committee Faculty of Public Health, Universitas Indonesia, under the approval No. 257/UN2.F10/PPM/00.02/2019.

Information on dietary diversity was obtained from mothers using a 24-hour food recall, which was collected by using an adapted food groups check list based on foods consumed as usual diet on the previous 24 hours. Then,

using the individual dietary diversity questionnaire, foods were classified into seven groups based on the WHO indicators, namely: 1. Grains, roots and tubers, 2. Legumes and nuts, 3. Dairy products, 4. Meat, fish, poultry, and liver/organ meats, 5. Eggs, 6. Vitamin A-rich fruits and vegetables, 7. Other fruits and vegetables. Besides using data from 24-hour food recalls, dietary diversity was also assessed by asking the mothers on whether their child had received foods from the standard seven

groups in the preceding day, without setting any minimum intake restrictions. Dietary diversity was calculated as the sum of food groups in the diet, which was considered “good” when subjects consumed four or more food groups, and “poor” when they consumed less than four food groups (FAO, 2011). Univariate analysis was conducted using descriptive statistics and the associations between variables were analyzed using chi-square test.

Table 1. Demographic and socio-behavioral characteristic of maternal and children

<i>Variable</i>	<i>n</i>	<i>%</i>
Nutritional status		
Stunting	69	34.5
Normal	131	65.5
Individual dietary diversity		
Poor	125	62.5
Good	75	37.5
Age group		
<2 years	113	56.5
≥2 years	87	43.5
Complementary feeding time		
Not appropriate (<6 or >6 mos.)	124	62.0
Appropriate (6 mos.)	76	38.0
Exclusive breastfeeding		
Yes	77	38.5
No	123	61.5
Mother's parity		
Less	62	31.0
More	138	69.0
Mother's age during pregnancy		
Risky	66	33.0
Not risky	134	67.0
Child's history of infections		
Yes	72	36.0
No	128	64.0

RESULTS

The number of subjects in this study was 200 children aged 6–59 months, who were domiciled in the Babakan Madang subdistrict, Bogor district, West Java, Indonesia. The subjects were mostly aged <2 years (56.5%) and dominated by boys (53.5%). Most mothers of the subjects did not have any jobs or were housewives (93.0%) and had completed a minimum of elementary school education (84.0%).

The subjects’ fathers mostly worked as labourers or were in service (82.2%) and had completed a minimum of senior high school education (35.0%) (Table 1).

The prevalence of stunting in this study was 34.5%, and 62.5% of the children had poor dietary diversity. Responses to the questionnaire showed that only about 38.5% of the mothers in the study practised exclusive breastfeeding, and this was similar to the

Table 2. Dietary diversity and other factors associated with stunting (n=200)

Variable	Stunting				OR	p-value	95% CI
	Yes		No				
	n	%	n	%			
Individual dietary diversity							
Poor	51	40.8	74	59.2	2.182	0.023*	1.152–4.134
Good	18	24.0	57	76.0			
Age group							
<2 years	30	26.5	83	73.5	0.445	0.011*	0.246–0.806
≥2 years	39	44.8	48	55.2			
Complementary feeding time							
Not appropriate (<6 or >6 mos.)	46	37.1	78	62.9	1.359	0.405	0.738–2.501
Appropriate (6 mos.)	23	30.3	53	69.7			
Exclusive breastfeeding							
No	48	39.0	75	61.0	1.707	0.086	0.919–3.168
Yes	21	27.3	56	72.7			
Mother’s parity							
Less	24	38.7	38	61.3	1.305	0.497	0.700–2.433
More	45	32.6	93	67.4			
Mother’s age during pregnancy							
Risky	22	33.3	44	66.7	0.926	0.932	0.497–1.725
Not risky	47	35.1	87	64.9			
Child’s history of infections							
Yes	27	37.5	45	62.5	0.814	0.607	0.445–1.488
No	42	32.8	86	67.2			

Note: p-value is the significance of chi-squared test; OR is odds ratio; CI is confidence interval *p<0.05

appropriate complementary feeding time of 6 months (38.0%). Nonetheless, more than half of the children did not have a history of having infectious diseases (64.0%). Most mothers of the subjects had a history of previous childbirth, i.e. high parity (69.9%), and their age during pregnancy was classified as non-risky (67.0%) (Table 2).

Bivariate analysis showed that there were two variables that had significant associations with stunting: poor individual dietary diversity ($p=0.023$; $OR=2.182$; 95% CI: 1.152–4.134) and age group <2 years ($p=0.011$; $OR=0.445$; 95% CI: 0.246–0.806). The results also showed that age group <2 years had a significant association with poor dietary diversity ($p=0.002$; $OR=2.474$; 95% CI: 1.367–4.447). In comparison, time of complementary feeding, exclusive breastfeeding, mother's parity, mother's age during pregnancy, and child's history of infections were not associated with stunting.

DISCUSSION

Globally, linear growth deficit in children is a nutritional problem. Results in this study indicated that the percentage of children aged 6–59 months who were stunted was 34.5%. Moreover, the 2017 Nutritional Status Assessment in West Java showed that 29.6% of the children were stunted, an increase of 2.1% from the previous year (Kemenkes RI, 2017). According to WHO, a region is classified as having a severe problem if the prevalence of stunting is around 30%–39%, and a serious problem if the prevalence of stunting is >40% (WHO, 2010). Stunting can have a very bad impact on children's growth, especially related to their cognitive, motor, and emotional functions, as well as their future potential (Walker *et al.*, 2007).

Stunting can be caused by several factors, one of which is food intake. Based on the results of this study, it was seen that children who consumed <4

Table 3. Dietary diversity and other factors associated with stunting ($n=200$)

Variable	Dietary Diversity				OR	p-value	95% CI
	Poor		Good				
	n	%	n	%			
Age group							
<2 years	81	71.7	32	28.3	2.474	0.002*	1.367-4.447
≥2 years	44	50.6	43	49.4			
Complementary feeding time							
Not appropriate (<6 or >6 mos.)	83	66.9	41	33.1	1.639	0.098	0.911-2.947
Appropriate (6 mos.)	42	55.3	34	44.7			
Exclusive breastfeeding							
No	67	54.5	56	45.5	1.845	0.082	1.194-2.852
Yes	58	75.3	19	27.4			
Child's history of infections							
Yes	80	62.5	48	37.5	1.000	1.000	0.551–1.816
No	45	62.8	27	37.5			

* $p<0.05$

groups of foods had a 2.18 times higher risk of becoming stunted compared to children who consumed >4 groups of foods. This result is in agreement with a previous study conducted in Namibia (OR = 1.095; 95% CI: 1.021–1.174), and is reinforced by the results of a study in Sedayu Yogyakarta (OR=12.11; 95% CI: 5.83–25.10) (Paramashanti *et al.*, 2017). The higher the score of diversity in food consumption, the more diverse the types of foods consumed by children. Thus, the variety of foods consumed will tend to meet the adequacy of nutrients that can affect the nutritional status of children (Habte & Krawinkel, 2016).

Dietary diversity in children must cover at least four of the seven food groups, which must consist of staple foods, side dishes, vegetables and fruits (Wantina, Rahayu & Yuliana, 2017). In addition, the variety in foods should also be introduced early in children under <5 years old because every food group contains essential nutrients that can complete their nutritional needs (Rah *et al.*, 2010). In this study, children mostly consumed <4 food groups per day (62.5%). There were even cases where the mothers gave their children only three food groups in a day, including breast milk. In fact, sometimes children were given the same type of food consecutively for several days. The majority of the children (87.0%) consumed grains, such as rice and bread, while consumption of eggs, legumes and animal source foods were low. Animal source foods like meat, milk and eggs have a variety of micronutrients including vitamin A, vitamin B-12, riboflavin, calcium, iron and zinc that are difficult to obtain in adequate quantities from plant source foods alone (Khamis *et al.*, 2019).

Several previous studies showed results that were different from those obtained in this study, such as studies conducted in Bangladesh and Cambodia. Both of these showed an association

between dietary diversity and stunting, but the power of association was quite weak (Darapheak *et al.*, 2013; Rah *et al.*, 2010). These differences could have been caused by differences in the instruments used. In these studies, household dietary diversity score (HDDS) was used, which does not have specific and relevant targets in any population group; whereas this study used the individual dietary diversity score (IDDS), which targets children more specifically because of the importance given to micronutrient adequacy for growth and development (Mark & Agnes, 2008). IDDS was used as a measure of nutritional quality for every subject to reflect nutrient adequacy.

Our analyses showed that children <2 years of age were significantly protected from being stunted than children aged ≥ 2 years. However, this does not prove that they will be free from stunting. The difficulty in clearly detecting the occurrence of stunting in children aged <2 years is one of the main factors that causes a greater risk of stunting in children aged ≥ 2 years. The suboptimal growth related to increased age might be derived from the challenges associated with the feeding transition from breastfeeding to complementary feeding (Titaley *et al.*, 2019). On the other hand, we found that children aged <2 years had a significantly increased likelihood of having poor dietary diversity than those aged ≥ 2 years. Previous studies have found that younger children were significantly associated with inadequate dietary diversity; and it can be related to the delay in the initiation of complementary feeding in the form of solid, semi-solid or soft foods (Custodio *et al.*, 2019). This makes stunting possible in children aged <2 years.

Children with stunting at <2 years were reported to experience worse psychological functions (more anxious and depressed) in adolescence than children who were not stunted at <2

years of age (Darapheak *et al.*, 2013). In addition, it has been reported that such stunting can also cause hyperactive behaviours and increase the levels of opposition or aggression in children (Walker *et al.*, 2007).

The growth process in children aged ≥ 2 years tend to be slower, thus the chance for catch-up growth would be lower than children aged < 2 years (Darapheak *et al.*, 2013). Age > 2 years is the time when children grow rapidly in their cognitive and motor developments. Therefore, peak physical condition, which can only be attained through appropriate nutrition, is needed to support these developments (Darapheak *et al.*, 2013; Zottarelli, Sunil & Rajaram, 2007). Increasing age must be accompanied by an increasing diversity of foods consumed (FAO, 2011). So, children at this age also need more attention than children < 2 years in terms of food intake because of their needs for higher energy and more varied foods for nutrient fulfilment.

CONCLUSION

The results of this study showed that there was a strong association between dietary diversity and stunting in children aged 6–59 months in Babakan Madang subdistrict of Indonesia. Individual dietary diversity score can be used as an indicator of dietary quality. Children who did not eat a variety of foods and thus had poor food intake bore 2.18 times higher risk of being stunted compared with children who had good food intakes. Finally, dietary education would be the most effective strategy to deliver messages about child feeding practices, especially on dietary diversity.

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Authors' contributions

LT, conducted the study, data analysis and interpretation, prepared the draft of the manuscript, assisted in drafting of the manuscript, reviewed the manuscript; TS, led the data collection, conceptualised and design the study, reviewed the manuscript; RADS, led the data collection, advised on the data analysis and interpretation and reviewed the manuscript; AS, advised on the data analysis and interpretation and reviewed the manuscript.

Conflict of interest

The authors declare that there were no conflicts of interest in this study.

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SHORT COMMUNICATION

Nutritional composition of indigenous durian varieties

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ABSTRACT

Introduction: Data on nutrients of indigenous durians are useful for selecting suitable varieties for future cultivation and conservation. The objective of this study is to investigate the nutrient composition (proximate composition, dietary fibre, minerals, sugars, and fatty acids) of 17 indigenous durian varieties from Thailand. **Methods:** The edible part of each variety was collected, freeze dried, and kept in a freezer until analysis. All parameters were analysed by International Organization for Standardization (ISO) 17025 accredited laboratories using the Association of Official Analytical Chemists (AOAC) standards or well-validated methods. **Results:** All varieties of durian contained protein, fat [2.2-3.4g and 2.6-6.1g/100g fresh weight (FW), respectively], and carbohydrate (20.0-39.5g/100g FW). Sugars were predominantly found (14.2-21.8g/100g FW) and sucrose was the major form of sugars (50.0-90.0%). For the most part, all varieties contained considerable amounts of potassium, sulphur, and phosphorus. Oleic acid (C18:1n9) was the major monounsaturated fatty acid and palmitic acid (16:0) was the major saturated fatty acid (27.9-51.9% and 35.6-48.3%, respectively) in all varieties. **Conclusion:** Varieties of *Kob-wat-kuay*, *Kob-sao-noi*, and *Kob-wai* provided several beneficial compounds but also had unhealthy nutrients in small amounts. This food composition database information is beneficial for selecting good varieties for the purpose of conservation, healthy consumption, and export promotion.

Keywords: Durian, food composition, nutrient, fatty acid

INTRODUCTION

Durian (*Durio zibethinus* L.) is well-recognised as the king of fruits and is widespread among Southeast Asian countries including Thailand. Although durian can grow in various regions of Thailand, the Nonthaburi province, a

suburb of Bangkok, is well-known as the best place for growing durian due to its taste and high biodiversity. However, severe flooding in 2011 caused serious damage to many durian orchards. After that, various varieties of indigenous durians have been chosen and grown by

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durian gardeners in different provinces of Thailand.

Data on nutrients, sugars, fatty acids, and antioxidant activities of indigenous durians are useful for selecting suitable varieties for future cultivation and conservation. However, such information for indigenous durian varieties is limited. A study by Charoenkiatkul *et al.* (2016) in the Nonthaburi province showed that indigenous durian varieties, such as *Chani* and *Kob-ta-kam*, exhibited higher levels of nutrients, bioactive compounds, and antioxidant activities than popular durian varieties, such as *Mon-thong* and *Kra-dum*. Data on the nutritive value of popular durian varieties such as *Mon-thong*, which is grown in the Rayong and Chantaburi provinces in eastern Thailand have been reported (Haruenkit *et al.*, 2007; Charoensiri *et al.*, 2009; Haruenkit *et al.*, 2010). Ho and Bhat (2015) also presented information about the nutritional composition of popular commercial durian varieties. The Thai and ASEAN Food Composition Database contain information about the most popular and some indigenous durian varieties, but the data are limited and incomplete (Puwastien *et al.*, 2015), especially in terms of proximate composition, as well as some minerals and vitamins. Consequently, 17 varieties of indigenous durian fruits were studied in terms of proximate composition, dietary fibre, minerals, sugars and fatty acid composition.

MATERIALS AND METHODS

Food sampling and sample preparation

17 varieties of indigenous durians (*Durio zibethinus* L.) were studied, namely, *Baht-thong-kum*, *Chao-koa*, *Chom-phu-sri*, *Dao-kra-jai*, *Keng-tong*, *Kob-mae-tao*, *Kob-pi-kul*, *Kob-sao-noi*, *Kob-ta-khao*, *Kob-ta-tao*, *Kob-wai*, *Kob-wat-kuay*, *Kum-pun-chao-kom*, *Kum-pun-nur-khao*, *Kum-pun-puang*, *Sao-chom*, and

Tong-yoi-chat. The durian fruits were selected and three fruits of each variety were collected by local gardeners in the Nonthaburi province during April to May 2011, before the severe flooding occurred. More than 50 years ago, these indigenous durian varieties were selected to grow in the Nonthaburi province, Thailand. According to local gardeners, the optimum ripeness of the durian fruits were 3-7 days after harvest, depending on the variety, combined with the characteristics of the flesh adhering to the thick shell (Haruenkit *et al.*, 2010). After collection, each durian fruit was transported to the Institute of Nutrition, Mahidol University laboratory. After ripening, each durian was peeled and the edible part was cut into pieces using a plastic knife. Each sample was divided into two portions; first portion used for moisture analysis and the second portion used for freeze drying. For moisture analysis, the durian flesh was homogenised, put in an acid-washed plastic bottle and kept at -20°C until ready for analysis. For the preparation of freeze-dried samples, the pieces of each sample were put into a freeze-drying machine for 36 h until dried and then homogenised into fine powder. They were packed in vacuum-sealed laminated aluminium foil bags and stored at -20°C until analysis.

Nutrient determination

Standard Association of Official Analytical Chemists (AOAC) methods (AOAC International, 2019) were used for proximate, minerals, sugars and fatty acids analyses. All samples were analysed at the ISO 17025 accredited laboratory, Institute of Nutrition, Mahidol University, which provided international standards for laboratory quality systems. The results of measurements from three composite samples were presented as mean±standard deviation (SD) on a fresh weight (FW) basis.

Proximate composition

Standard AOAC method no. 952.45 (AOAC International, 2019) using hot air oven was used for moisture analysis. Method no. 981.10 (AOAC International, 2019) using the Kjeldahl method was used for total nitrogen analysis, and calculated into protein content using specific (Jones) factors. Method no. 945.16 (AOAC International, 2019) was applied for crude fat analysis by acid digestion prior to continuous extraction using petroleum ether in Soxtec system. Method no. 945.46 (AOAC International, 2019) was used for ash analysis by incinerating all organic matters at $550\pm 5^\circ\text{C}$. Method no. 991.43 (AOAC International, 2019) was applied for total dietary fibre analysis using enzymatic gravimetric method. Available carbohydrate was calculated using the following formula: $100 - (\text{moisture} + \text{protein} + \text{fat} + \text{ash} + \text{dietary fibre})$ and energy was calculated by Atwater factor.

Minerals

Method no. 984.27 (AOAC International, 2019) using acid digestion in a closed Teflon vessel was employed for determining magnesium, iron, copper, and zinc using an inductively coupled plasma optical emission spectrophotometer (ICP-OES). The acid solution was analysed by flame atomic absorption spectrophotometer (AAS) for the determination of calcium, sodium, and potassium using method no. 975.03 (AOAC International, 2019). The acid solution was also determined for phosphorus by gravimetric method (AOAC International, 2019).

Sugars

Sugars including fructose, glucose and sucrose contents were determined using a high pressure liquid chromatography (HPLC) with evaporative light scattering detector (ELSD), method no. 980.13

(AOAC International, 2019). Sum of all individual sugar was reported as total sugars.

Fatty acids

After fat extraction, fatty acids were extracted using hydrolytic methods. Extracted fat was dissolved in petroleum ether, then methylated to fatty acid methyl esters (FAMES) using boron trifluoride in methanol. Fatty acids were separated by capillary columns installed in the gas chromatography (GC) system against C17:0 internal standard, method no. 996.06 (AOAC International, 2019).

Quality control of laboratory analysis

All analytical methods were validated or verified to fulfill the requirement of ISO/IEC 17025 accreditation. In-house quality control (QC) samples were prepared and measured for every batch of samples including milk powder (for total nitrogen, moisture and crude fat analyses), and defatted soybean flour (for ash, total dietary fibre, and mineral analyses). The results of QC samples for each batch were within the mean of $\pm 2SD$ of the assigned values as presented in a previous study (Judprasong *et al.*, 2013). The percent relative standard deviation (RSD) of the assigned values was also no more than 10.

RESULTS AND DISCUSSION

Nutrients

Proximate compositions

The edible portion, energy, proximate compositions, and sugars of the 17 durian varieties are shown in Table 1. Edible portions ranged from $23.5\pm 2.1\%$ in the *Baht-thong-kum* variety to $30.5\pm 1.3\%$ in the *Kob-ta-tao* variety. The major component was water, which was the lowest in the *Chao-koa* variety ($54.2\pm 0.1\text{g}/100\text{g}$ edible FW) and the highest in the *Kob-sao-noi* variety ($73.3\pm 2.3\text{g}/100\text{g}$ FW). The durian

Table 1. Proximate composition and sugar content of 17 varieties of indigenous durian (per 100g edible FW)[†]

Variety of durian	Edible (%)	Energy (kcal)	Moisture (g)	Protein (g)	Fat (g)	Ash (g)	Total dietary fibre (g)	Available carbohydrate (g)	Total sugar (g)	Fructose (g)	Glucose (g)	Sucrose (g)
<i>Baht-thong-kum</i>	23.5±2.1 ^c	170±1 ^b	61.5±0.1 ^c	3.2±0.1 ^b	4.7±0.1 ^d	1.3±0.1 ^b	1.3±0.1 ^f	28.1±0.1 ^c	18.4±0.1 ^b	0.0±0.0 ^d	0.0±0.0 ^d	18.4±0.1 ^b
<i>Chao-koa</i>	24.3±2.4 ^c	187±1 ^a	54.2±0.1 ^g	2.5±0.1 ^d	2.6±0.1 ^b	1.2±0.1 ^b	2.3±0.1 ^c	37.3±0.1 ^a	18.1±0.1 ^b	0.2±0.0 ^b	0.3±0.0 ^b	17.6±0.1 ^c
<i>Chom-phu-sri</i>	26.7±2.9 ^b	132±1 ^d	69.7±0.1 ^b	2.9±0.1 ^c	3.9±0.1 ^c	1.3±0.1 ^b	1.9±0.1 ^d	20.4±0.1 ^f	14.2±0.1 ^f	0.0±0.0 ^d	0.0±0.0 ^d	14.2±0.0 ^f
<i>Dao-kra-jai</i>	25.5±2.1 ^b	122±8 ^d	71.2±1.9 ^b	3.2±0.1 ^b	3.4±0.1 ^f	1.5±0.1 ^a	2.1±0.1 ^d	19.0±1.2 ^f	18.5±0.8 ^b	0.3±0.1 ^a	0.3±0.0 ^b	18.6±0.5 ^b
<i>Keng-tong</i>	24.3±1.9 ^c	153±1 ^c	63.5±0.3 ^d	2.7±0.1 ^b	3.0±0.1 ^g	1.3±0.1 ^b	1.6±0.1 ^e	28.0±0.2 ^c	16.4±0.9 ^d	0.1±0.1 ^c	0.2±0.0 ^c	16.1±1.0 ^d
<i>Kob-mae-tao</i>	27.4±2.2 ^a	149±1 ^c	65.7±0.1 ^c	2.9±0.1 ^c	4.5±0.1 ^d	1.5±0.1 ^a	2.2±0.1 ^c	23.2±0.1 ^d	16.5±0.1 ^d	0.1±0.0 ^c	0.3±0.0 ^b	16.1±0.1 ^d
<i>Kob-pi-kul</i>	24.2±2.1 ^c	163±10 ^b	62.8±1.7 ^d	3.3±0.2 ^b	4.5±0.8 ^d	1.5±0.1 ^a	1.1±0.1 ^g	26.9±0.6 ^c	17.2±1.1 ^c	0.0±0.0 ^d	0.0±0.0 ^d	17.2±1.1 ^c
<i>Kob-sao-noi</i>	26.0±2.4 ^b	113±1 ^c	73.3±2.3 ^a	2.7±0.9 ^c	2.9±1.2 ^g	1.1±0.4 ^c	2.0±0.7 ^d	18.1±1.5 ^f	16.4±2.0 ^d	0.2±0.2 ^b	0.3±0.1 ^b	17.2±1.1 ^c
<i>Kob-ta-khao</i>	28.0±2.5 ^a	162±1 ^b	64.8±0.1 ^d	3.2±0.1 ^b	6.1±0.1 ^a	1.1±0.1 ^c	2.7±0.1 ^b	22.2±0.2 ^d	21.8±0.2 ^a	0.4±0.0 ^a	0.5±0.0 ^a	20.9±0.1 ^a
<i>Kob-ta-tao</i>	30.5±1.3 ^a	134±8 ^c	69.6±1.7 ^b	2.2±0.1 ^c	4.1±0.2 ^c	0.9±0.4 ^d	2.3±0.4 ^c	20.9±1.5 ^e	19.2±1.0 ^b	0.1±0.1 ^c	0.2±0.0 ^c	18.8±0.9 ^b
<i>Kob-uai</i>	26.6±1.7 ^b	123±1 ^d	70.2±0.1 ^b	2.5±0.1 ^d	2.6±0.1 ^b	1.3±0.1 ^b	2.1±0.1 ^d	21.2±0.1 ^e	12.6±0.1 ^g	0.1±0.0 ^c	0.3±0.0 ^b	12.3±0.1 ^f
<i>Kob-wat-kuay</i>	25.0±3.2 ^b	128±1 ^d	70.1±0.1 ^b	3.2±0.1 ^b	3.9±0.1 ^e	1.5±0.1 ^a	2.7±0.1 ^b	18.6±0.2 ^f	15.9±0.3 ^e	0.1±0.0 ^c	0.3±0.0 ^b	15.5±0.1 ^d
<i>Kum-pun-chao-kom</i>	27.8±2.5 ^a	177±1 ^a	58.3±0.3 ^f	2.7±0.1 ^c	4.0±0.2 ^e	1.3±0.2 ^b	2.3±0.3 ^c	31.4±0.1 ^b	17.7±0.7 ^c	0.3±0.1 ^a	0.5±0.1 ^a	16.9±0.8 ^c
<i>Kum-pun-nur-khao</i>	29.3±3.1 ^a	166±1 ^b	62.3±0.1 ^d	2.4±0.1 ^d	4.6±0.1 ^d	1.4±0.1 ^a	1.0±0.1 ^g	28.4±0.1 ^c	15.7±0.2 ^e	0.1±0.0 ^c	0.0±0.0 ^d	15.7±0.0 ^d
<i>Kum-pun-puang</i>	28.2±2.8 ^a	165±1 ^b	62.9±0.1 ^d	3.4±0.1 ^b	5.7±0.1 ^b	1.2±0.1 ^b	3.7±0.2 ^a	23.1±0.1 ^d	17.5±0.1 ^c	0.1±0.0 ^c	0.3±0.0 ^b	17.0±0.1 ^c
<i>Sao-chom</i>	25.8±2.9 ^b	160±1 ^b	64.3±0.1 ^d	2.9±0.1 ^c	5.3±0.1 ^c	1.2±0.1 ^b	2.1±0.1 ^d	24.1±0.1 ^d	20.8±0.5 ^a	0.2±0.0 ^b	0.3±0.0 ^b	19.3±0.1 ^a
<i>Tong-yoi-chat</i>	26.6±2.4 ^b	143±1 ^c	67.6±0.1 ^c	3.8±0.1 ^a	4.4±0.1 ^d	1.5±0.1 ^a	1.3±0.1 ^f	21.4±0.1 ^e	18.5±0.2 ^b	0.0±0.0 ^d	0.0±0.0 ^d	18.5±0.0 ^b

[†] Values are mean±SD of triplicate analyses from three composite samplesa, b, c, d, e, f, g Different superscript letters in the same column indicate significant difference ($p < 0.05$) as assessed by analysis of variance (ANOVA), followed by Fisher's Least-Significant Difference (LSD)

Table 2. Mineral content (mg/100g edible FW) and fatty acid composition (%) of 17 varieties of indigenous durians[†]

Variety of durian	Minerals content (mg/100g edible FW)										Fatty acid composition (%)				P:M:S
	Ca	Mg	P	Na	K	S	Fe	Cu	Zn	SFA	MUFA	PUFA			
<i>Baht-thong-kum</i>	2±0 ^b	15±1 ^c	41±1 ^b	19±1 ^b	451±2 ^d	63±1 ^a	0.21±0.01 ^e	0.10±0.01 ^c	0.36±0.0 ^b	38.28±1.40 ^d	54.68±0.98 ^a	7.04±0.20 ^d	0.2:1.4:1.0		
<i>Chao-kooa</i>	1±0 ^c	19±0 ^b	45±1 ^a	14±1 ^c	480±2 ^d	46±1 ^d	0.27±0.01 ^d	0.25±0.01 ^d	0.17±0.02 ^f	46.29±0.95 ^b	45.31±0.79 ^c	8.39±0.32 ^c	0.2:1.0:1.0		
<i>Chom-phu-sri</i>	3±0 ^b	17±1 ^b	31±1 ^d	13±1 ^c	514±13 ^c	62±1 ^a	0.32±0.02 ^c	0.07±0.01 ^d	0.14±0.01 ^g	41.32±0.65 ^c	55.86±0.66 ^a	2.81±0.44 ^f	0.1:1.4:1.0		
<i>Dao-kra-jai</i>	4±1 ^a	23±1 ^a	36±1 ^c	15±1 ^c	534±53 ^c	64±1 ^a	0.23±0.02 ^c	0.17±0.01 ^b	0.32±0.09 ^c	46.61±0.40 ^b	39.99±0.28 ^d	13.40±0.12 ^a	0.3:0.9:1.0		
<i>Keng-tong</i>	4±0 ^a	21±1 ^a	41±3 ^b	11±5 ^d	643±42 ^b	57±2 ^b	0.32±0.01 ^c	0.18±0.01 ^b	0.20±0.01 ^c	45.50±0.29 ^b	43.93±0.37 ^c	10.57±0.15 ^b	0.2:1.0:1.0		
<i>Kob-mae-tao</i>	4±0 ^a	23±0 ^a	42±1 ^b	21±1 ^a	676±3 ^a	55±1 ^b	0.47±0.01 ^a	0.22±0.01 ^a	0.46±0.01 ^a	52.01±0.46 ^a	44.55±0.46 ^c	3.44±0.34 ^f	0.1:0.9:1.0		
<i>Kob-pi-kul</i>	4±1 ^a	20±1 ^b	47±4 ^a	11±2 ^d	601±96 ^b	64±1 ^a	0.41±0.05 ^a	0.16±0.03 ^b	0.30±0.01 ^c	38.48±0.53 ^d	58.78±0.73 ^a	2.74±0.24 ^g	0.1:1.5:1.0		
<i>Kob-sao-noi</i>	2±0 ^b	19±3 ^b	40±8	12±5 ^c	450±43 ^d	47±2 ^d	0.35±0.07 ^b	0.24±0.04 ^a	0.22±0.07 ^c	39.06±0.73 ^d	55.78±0.84 ^a	5.16±0.28 ^e	0.1:1.4:1.0		
<i>Kob-ta-khao</i>	2±0 ^b	20±0 ^b	43±1 ^b	17±0 ^b	473±2 ^d	51±1 ^c	0.36±0.01 ^b	0.19±0.01 ^b	0.32±0.01 ^c	53.77±0.93 ^a	36.33±0.55 ^c	9.90±0.80 ^c	0.2:0.7:1.0		
<i>Kob-ta-tao</i>	5±2 ^a	15±1 ^c	37±2 ^c	10±3 ^d	411±75 ^c	44±3 ^d	0.30±0.01 ^d	0.09±0.02 ^d	0.15±0.02 ^f	40.77±0.56 ^c	53.41±0.94 ^b	5.82±0.43 ^c	0.1:1.3:1.0		
<i>Kob-wai</i>	6±0 ^a	17±0 ^c	38±1 ^c	19±3 ^a	511±24 ^c	51±1 ^c	0.34±0.01 ^b	0.17±0.01 ^b	0.25±0.01 ^d	40.39±0.49 ^c	51.56±0.45 ^b	8.05±0.58 ^d	0.2:1.3:1.0		
<i>Kob-wat-kuay</i>	6±0 ^a	20±0 ^b	49±1 ^a	10±1 ^d	610±12 ^b	58±1 ^b	0.44±0.01 ^a	0.24±0.01 ^a	0.41±0.02 ^a	40.87±0.44 ^c	50.22±0.50 ^b	8.91±0.33 ^c	0.2:1.2:1.0		
<i>Kum-pun-chao-kom</i>	5±0 ^a	18±3 ^b	42±3 ^b	11±2 ^d	457±30 ^d	59±5 ^b	0.22±0.02	0.16±0.02 ^b	0.21±0.03 ^c	48.80±0.37 ^b	43.80±0.38 ^c	7.40±0.10 ^d	0.2:0.9:1.0		
<i>Kum-pun-nur-khao</i>	4±0 ^a	19±1 ^b	42±1 ^b	13±1 ^c	512±3 ^c	47±1 ^d	0.35±0.01 ^b	0.11±0.01 ^c	0.20±0.01 ^c	46.55±0.34 ^b	51.19±0.62 ^b	2.26±0.22 ^g	0.1:1.1:1.0		
<i>Kum-pun-puang</i>	5±0 ^a	18±0 ^b	44±1 ^a	14±3 ^c	406±29 ^e	53±1 ^c	0.28±0.01 ^d	0.14±0.01 ^c	0.28±0.01 ^d	40.56±0.71 ^c	51.50±0.42 ^b	7.93±0.19 ^a	0.2:1.3:1.0		
<i>Sao-chom</i>	2±0 ^b	19±0 ^b	37±2 ^c	12±1 ^c	538±3 ^c	65±2 ^a	0.31±0.01 ^c	0.16±0.01 ^b	0.13±0.01 ^g	38.98±0.66 ^d	55.32±0.73 ^a	5.71±0.31 ^e	0.1:1.4:1.0		
<i>Tong-yoi-chat</i>	5±0 ^a	18±1 ^b	45±1 ^a	14±1 ^c	534±8 ^c	46±1 ^d	0.40±0.01 ^a	0.08±0.01 ^d	0.32±0.01 ^c	41.14±0.86 ^c	56.58±0.53 ^a	2.28±0.28 ^g	0.1:1.4:1.0		

[†] Values are mean±SD of triplicate analyses from three composite samples

^{a, b, c, d, e, f, g} Different superscript letters in the same column indicate significant difference ($p < 0.05$) as assessed by ANOVA followed by Fisher's LSD

varieties provided a noteworthy amount of protein (2.4-3.8g/100g FW), which was equal to 5.3-10.6g/100g dry weight (dry matter, DM). The protein levels in all varieties were higher than those reported previously with 4.2g/100g DM (Ho & Bhat, 2015). Fat levels ranged from 2.6±0.1g/100g FW (equal to 5.6g/100g DM) in *Chao-koa* and *Kob-wai* varieties to 6.1±0.1g/100g FW (equal to 14.8g/100g DM) in the *Kob-ta-khao* variety. Some durian varieties exhibited the same levels of fat as reported by Ho and Bhat (2015) (15.2g of fat/100g DM). All varieties of durian contained total dietary fibre (1.0-3.7g/100g FW equal to 2.5-10.1g/100g DM), which was similar to previous reports (3.4g/100g and 9.1g/100g DM, respectively) (Haruenkit et al., 2007; Gorinstein et al., 2011). The durian varieties also contained various amounts of available carbohydrates (18.1-37.3g/100g FW, equal to 63.3-81.8g/100g DM) and total sugars (14.2-21.8g/100g FW, equal to 38.8-67.5g/100g DM). Almost all of the sugars were found to be sucrose (92.7-100.0%).

Minerals

Of all the studied macro and trace elements [calcium (Ca), magnesium (Mg), phosphorus (P), sodium (Na), potassium (K), sulphur (S), iron (Fe), zinc (Zn), and copper (Cu)], K was the highest in amount, ranging from 406-676mg/100g FW (Table 2), which is equal to 1010-1895mg/100g DM. This range was close to that reported by Dembitsky et al. (2011) (1245mg/100g DM), and higher than that reported by Haruenkit et al. (2007) (574mg/100g DM). All durian varieties also contained S, P, Mg, and Na (44-65, 31-49, 15-23, and 10-21mg/100g FW, respectively), but they contained very low amount of calcium (1-6 mg/100g FM). These findings were in the same range as those reported in previous studies (Haruenkit

et al., 2007; Dembitsky et al., 2011). For trace elements, all durian varieties contained Fe, Cu, and Zn (0.21-0.47, 0.08-0.25, and 0.13-0.46mg/100g FM, respectively) in the same range as previous reports (Haruenkit et al., 2007; Dembitsky et al., 2011).

Fatty acids

Data on the sum of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) composition for all durian varieties are also presented in Table 2. Oleic acid (C18:1n9) was the major MUFA and palmitic acid (16:0) was the major SFA (27.91-51.88% and 35.63-48.27% of total fatty acids, respectively) in all varieties, which agreed well with a previous study (Haruenkit et al., 2010). Most of the indigenous varieties, except for six varieties (i.e. *Chao-koa*, *Dao-kra-jai*, *Keng-tong*, *Kob-mae-tao*, *Kob-ta-khao* and *Kum-pun-chao-kom*) contained MUFA>SFA>PUFA (50.22-58.78%, 38.28-41.32%, 2.26-8.91% of total fatty acids, respectively). The ratio of PUFA:MUFA:SFA (P:M:S ratio) in these varieties was 0.1-0.2:1.1-1.4:1.0. The P:M:S ratio in this group agreed well with the ratio reported by the MOPH Thailand (2002), which was 0.3:1.4:1.0.

CONCLUSION

17 indigenous durian varieties from the orchards of Nonthaburi province, Thailand, were compared in terms of their diversity in nutrients and fatty acid composition. Each durian variety has its unique health benefit depending upon its composition. Among the 17 varieties from this study, *Kob-wat-kuay*, *Kob-sao-noi*, *Kob-wai*, *Kob-pi-kul* and *Kum-pun-puang* varieties provided several beneficial nutrients. All durian varieties contained high sugar and carbohydrate levels and should be consumed in limited amounts on a daily basis. The

nutrient composition data of these durian varieties can be used to update the Thai and ASEAN food composition databases. They can also be used for selecting optimal durian varieties for the purpose of cultivation, conservation, healthy consumption, and exportation promotion.

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Authors' contributions

PT, prepared samples at laboratory, conducted data collection and analysis; SC, advised on the conceptualisation and designed the study; KK, conducted preparation and sample collection at studied areas; SS, conducted preparation and sample collection at studied areas; PS, conducted preparation and sample collection at laboratory, and conducted data collection; KJ, principal investigator, conceptualised and designed the study, collected samples at studied areas and prepared samples at laboratory, prepared the draft of the manuscript and reviewed the manuscript.

Conflict of interest

All authors declared that there is no conflict of interest in this study.

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Mango seed kernel flour (*Mangifera indica*): nutrient composition and potential as food

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ABSTRACT

Introduction: Mango seed kernel flour (MSKF) is a potential source of nutrition and antioxidant. In the present paper, we provide a complete data on the nutrient compositions of seven varieties of MSKF that are grown in Indonesia. The data can be used as a reference when MSKF is used for further processing in a variety of products. **Methods:** Seven varieties of MSKF were analysed for their proximate composition, antioxidant components, mineral content, and fatty acid profile. **Results:** Carbohydrate, crude protein, total lipid, crude fibre, and ash contents of MSKF were found to be 36.2-39.3%, 5.2-6.6%, 5.9-7.2%, 2.2-2.5%, and 2.9-5.5%, respectively. MSKF contained a considerable amount of antioxidant components at 62.4-72.9mg total polyphenols/g, carotenoid of 1.3-2.4mg/100g, vitamin E of 131.1-142.0mg/100g, and ascorbic acid of 66.8-73.1mg/100g. They also contained important minerals such as calcium at 25.2-36.8mg/100g, magnesium at 82.7-124.2mg/100g, potassium at 94.3-142.7mg/100g, phosphorus at 72.7-95.3mg/100g, and sodium at 21.7-37.5mg/100g. Stearic acid was the main saturated fatty acid, while oleic acid was the major unsaturated fatty acid. **Conclusion:** MSKF has the potential to be a good source of nutrition for humans.

Keywords: Mango, proximate, antioxidant, fatty acid, minerals

INTRODUCTION

Mango seed is a by-product of the processing of mango fruit, and until now it is still often considered an agricultural waste. It is composed of a hard and thick endocarp which encloses a kernel. Mango seed is about 10-25% of the fruit's total weight, while 45-85% of the seed's weight is the kernel, which is approximately 20% of the weight of the whole fruit. Scientific studies have reported on the importance of nutrition that is contained in mango seed kernel (MSK), especially for feeding

the ever-increasing human population. The problem of food insecurity in Asia and Africa in the next 35-50 years can cause hunger, and MSK is expected to help overcome this problem because it contains relatively high nutritional components.

In terms of anti-nutritional properties, the levels of phytic acid, hydrogen cyanide, and trypsin inhibitors are generally low and within the safe concentration which do not appear to pose a threat to life. The concentration

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of these properties are below the concentration of >20mg/100g that is considered as toxic.

In majority of the cases, by-products and even agricultural waste represent greater mass and often contain more active compounds. To fully exploit their biological potentials, by-products or waste with high nutritional content and functional values such as those contained in MSK can be used in the human diet. With the technology of nutritional preservation, mango seed kernel flour (MSKF) can be used as a composite flour or as a partial substitute for wheat flour in various food preparations, thus providing technological solutions. Related to the use of plant-based food sources as a composite flour for various food formulations, it is therefore essential to know more deeply the potential that is contained in MSKF.

Based on this purpose, this work aims to investigate more deeply the nutritional content of MSKF obtained from several different cultivars of mangoes grown in Indonesia. For the first time, this work investigates the potential of MSKF, which is critical as a preliminary study to provide data that are urgently needed by the highly developing food industry.

MATERIALS AND METHODS

Materials

Arumanis, *Golek*, *Manalagi*, *Indramayu*, *Madu*, *Kemang*, and *Gedong Gincu* varieties of mangoes cultivar in Indonesia were used in this study. All chemicals were sourced from Merck, Germany. The standard β -carotene was from Sigma (St. Louis, MO, USA), the standard α -tocopherol was from Sigma-Aldrich Co, and the standards for fatty acid methyl ester were from Supelco Inc., Bellefonte, PA (Supelco 37 Component FAME Mix).

Sample preparation and composition analysis

Preparation of MSKF samples were made according to Mas'ud *et al.* (2017). Proximate analyses i.e. moisture, protein, fat, fibre, and ash were carried out using the methods described in AOAC (1990). Carbohydrates were determined using the Luff-Schoorl method. Gas chromatography-mass spectrometry (GC-MS) was used to verify the fatty acids profile and vitamin E analysis. Total phenolic content was determined colorimetrically using the Folin-Ciocalteu's reagent method as described by Kriengsak *et al.* (2006). Ascorbic acid was determined by UV-Visible Spectrophotometry, carotenoid analysis according to Karnjanawipagul *et al.* (2010), and mineral analysis by S2 Ranger X-ray Spectrometer, according to the user's manual XRF (2012) by Bruker AXS GmbH, Ostliche Rheinbruckenstr, 49.76187 Karlsruhe, Germany.

RESULTS

The results of the proximate composition, antioxidant compounds, and mineral compounds of the seven varieties of MSKF grown in Indonesia are presented in Table 1, while their fatty acids profiles are presented in Table 2.

DISCUSSION

Proximate composition

The moisture, carbohydrate, crude protein, total lipid, crude fibre, and ash contents of MSKF were found to be 9.2-9.6%, 36.2-39.3%, 5.2-6.6%, 6.0-7.2%, 2.2-2.5%, and 2.9-5.5% on a dry weight basis, respectively. Related to the carbohydrate content, another study has reported that MSK contains carbohydrate of about 32.2-32.8% (Nzikou *et al.*, 2010). When compared to cassava and sweet potato,

Table 1. Proximate composition, antioxidant compounds, and mineral compounds of MSKF

Mango Varieties	Proximate composition of MSKF (%)					Antioxidant compounds of MSKF					Mineral compounds of MSKF (mg/ 100g)				
	Moisture	Carbohydrate	Protein	Fat	Ash	Crude fibre	Total phenols ^a mg/g	Carotene ^b mg/100g	Vitamin E mg/100g	Ascorbid acid mg/100g	Ca	Mg	K	P	Na
Arumanis	9.3	39.3	6.4	7.0	2.2	3.2	67.8	2.1	141.2	71.2	32.4	92.7	132.2	72.8	26.4
Golek	9.6	38.9	6.3	6.8	2.2	2.9	69.7	1.9	140.5	69.8	27.7	124.2	111.2	92.6	31.4
Manalagi	9.4	38.6	6.6	7.1	2.2	3.1	72.9	1.8	142.0	70.3	36.8	85.5	94.3	78.7	37.5
Indramayu	9.3	36.4	6.4	6.0	2.5	5.5	64.3	1.5	136.3	73.1	34.3	82.7	141.7	72.7	29.2
Madu	9.6	38.4	6.6	7.2	2.2	3.1	64.8	2.1	140.2	71.1	26.9	119.3	142.7	85.7	21.7
Kemang	9.3	36.2	5.5	6.5	2.5	5.0	62.4	1.3	133.3	66.8	28.5	127.3	136.4	83.6	32.4
Gedong gincu	9.2	36.3	5.2	6.6	2.5	5.1	70.3	2.4	131.1	76.1	25.2	88.2	127.5	95.3	33.4

^a Expressed as mg gallic acid equivalent^b Expressed as β -carotene equivalent**Table 2.** Fatty acid profile of MSKF (μ g)

Mango Varieties	C5:0	C12:0	C14:0	C16:0	C16:1	C17:0	C18:0	C18:1	C18:2	C20:0	C22:0	C23:0	C24:0
Arumanis	0.8	3.6	2.7	213.5	1.7	2.9	699.8	2456.0	190.2	48.9	8.4	1.9	10.1
Golek	0.6	3.6	2.8	209.1	1.6	2.9	706.7	2336.9	190.1	50.2	7.3	1.9	10.1
Manalagi	0.8	3.6	2.8	201.9	1.7	2.8	709.9	2329.9	186.3	46.4	8.1	1.9	8.1
Indramayu	0.6	3.1	2.7	199.8	1.5	2.8	701.9	2332.8	182.9	32.8	8.1	1.7	5.8
Madu	0.7	3.4	2.6	211.9	1.7	2.8	697.2	2414.9	189.1	45.7	8.4	1.6	9.9
Kemang	0.7	3.2	2.6	215.9	1.7	2.6	682.7	2405.7	172.8	36.6	7.6	1.9	6.7
Gedong gincu	0.7	3.5	2.7	215.3	1.7	2.6	692.8	2391.9	174.2	41.8	7.3	1.6	6.8

the carbohydrate content in MSK is equivalent to cassava and higher than a sweet potato. Even its protein and fat contents are higher. However, the fat content obtained in this study was lower than that shown by many other publications, maybe due to different mango varieties and differences in the location of growth.

In recent decades, mango seed lipids have attracted particular interest because they are a suitable source of fats that are beneficial to human health and nutrition. MSK fat has the typical characteristics of a vegetable butter (Muchiri, Mahungu & Gituanja, 2012). *Arumanis* mango seed contains 7.0% oil (Mas'ud *et al.*, 2017), which is rich in oleic and stearic acids. High stearic acid content makes mango seed oil have a semi-solid consistency; which can be used as a raw material for spreadable products. The lipid composition of MSK has also attracted the attention of scientists in recent years because of their unique physical and chemical characteristics. It is found that the physicochemical characteristics of mango seed fat are very similar to those of commercial cocoa butter (Jahurul *et al.*, 2015), and its properties within the normal range of edible oils.

The fibre value was 1.9% higher than bush mango (Ekpe, Umoh & Eka, 2007). MSKF contains high fibre, showing its potential as a good source of dietary fibre and plays an important role in reducing blood cholesterol levels. Based on the proximate composition analysis, it is known that MSK is a promising source of food.

According to Odunsi (2005), MSKF can be used in the manufacturing of cakes, cookies and breads for adults and children. Although MSKF cannot substitute maize, the composite flour application using MSKF and wheat flour or its combination with cassava or

sweet potato flour in the manufacturing of cakes, cookies and breads is thought to be able to produce higher quality products in terms of nutritional content as this would increase the fat, protein, and phenolic contents.

Antioxidant compounds

Antioxidant components contained in the MSKF are presented in Table 1. MSKF contained 62.4-72.9mg of total polyphenols/g. Carotenoid ranged from 1.3-2.4mg/100g, vitamin E 131.1-142.0mg/100g, and ascorbic acid 66.8-73.1mg/100g. MSKF contained different phenolic compounds such as tannin, vanillin, coumarin, cinnamic, ferulic acids, mangiferin, gallic, and caffeic acids. The concentration of phenolic compounds in the seed kernels was 4.6 times higher than those in the pulp, making these promising residues a good polyphenolic source. MSKF contained six major phenolic compounds mainly gallic acid, ellagic acid, gallates, coumaric, vanillin, and ferulic acid. Mas'ud *et al.* (2017) reported that extracted oil from MSKF contained polyphenolics of 67.8mg GAE/g oil. The carotenoid values obtained in this study were around 1.3-2.4mg/100g; while other researchers have found it to be 0.79mg/100g.

MSK could be used as a potential source for functional food ingredients due to its high quality of fat, as well as high levels of natural antioxidants. With the emergence of various diseases, the food industry is currently focused on the production of functional foods, and the nutritional potential and antioxidant content of MSKF are expected to be utilised optimally for the development of such products.

Mineral compounds

MSKF contained high amounts of potassium, phosphorus, and

magnesium, depending on the variety (Table 1). The contents of calcium ranged from 25.2-36.8mg/100g, magnesium 82.7-124.2mg/100g, potassium 94.3-142.7mg/100g, phosphorus 72.7-95.3mg/100g, and sodium 21.7-37.5mg/100g. The calcium values obtained in this study were lower than the reported 49mg/100g (Elegbede, Achoba & Richard, 1995) and 450mg/100g (Odunsi, 2005) for Nigeria mango, but higher than 10.2mg/100g (Nzikou *et al.*, 2010). The magnesium values were lower than 980mg/100g (Odunsi, 2005) but higher than 22.3mg/100g (Nzikou *et al.*, 2010). The potassium values were higher than 6mg/100g (Odunsi, 2005) but lower than 158mg/100g (Nzikou *et al.*, 2010) and 365mg/100 g (Elegbede, Achoba & Richard, 1995). The phosphorus values were higher than 20mg/100g (Nzikou *et al.*, 2010) but lower than 140mg/100g (Elegbede, Achoba & Richard, 1995) and 230mg/100g (Odunsi, 2005). The sodium values were lower than 150mg/100g (Odunsi, 2005) but higher than 2.7mg/100g (Nzikou *et al.*, 2010).

Mineral nutrition is very important, such as the need of potassium and phosphorus every day. Mango seed contains mineral compounds such as potassium, copper, zinc, manganese, iron, and selenium. The presence of mineral compounds has a crucial role in terms of food safety and general product longevity, although the overall quality of the product is generally defined by its culinary benefits (Mas'ud *et al.*, 2017).

Fatty acids profile

In general, the results revealed that the total saturated fatty acids and unsaturated fatty acids of MSK oil were about 28% and 72%, respectively. Unsaturated fatty acids were higher than saturated fatty acids. Oleic acid was the major unsaturated fatty acid, followed by linoleic acid, while stearic acid was

the main saturated fatty acid.

Based on Table 2, it can be seen that MSKF oil is rich in oleic and stearic fatty acids. High oleic content indicates that the oil is good for health, while high stearic fatty acid indicates that the oil is stable and tolerant towards rancidity. The high content of stearic fatty acid makes MSK fat has the typical characteristics of a vegetable butter. Besides, it is also rich in linoleic fatty acids, which are also very good for health. This makes MSK a valuable source for producing high-value edible oils, as the values of its refractive index, acid, saponification, and iodine are generally within the standard specifications. Furthermore, MSK fat has a lower IC₅₀ (half maximal inhibitory concentration) value than butylated hydroxytoluene (BHT) as a reference, allowing its ideal application as a functional or enriched food ingredient. In summary, the fat content of MSK makes this oil recommendable to the food, pharmaceutical, and cosmetic industries.

CONCLUSION

The present study has highlighted the potential of MSKF as a source of food. MSKF contained considerable amounts of carbohydrate, antioxidant components such as polyphenols, carotenoid vitamin E, and ascorbic acid. Stearic acid was the main saturated fatty acid, and oleic acid was the major unsaturated fatty acid. Other than that, it also contained good amounts of calcium, magnesium, potassium, phosphorus, and sodium. Although more research is needed, MSKF which is often considered as a waste seems promising as a food. MSKF can be used in the manufacturing of cakes, cookies and breads, both singly or as a composite with cassava and sweet potato flour. MSKF is expected to help overcome the problem of food

insecurity in Asia and Africa, which can cause hunger and is feared to occur in the next 35-50 years.

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Authors' contributions

FM, the leader of researcher, conceptualised, designed the research, and prepared manuscripts; AR, carried out sample analysis and data collection; MS, conducted research and assisted in the preparation of the manuscript.

Conflict of interest

The authors have no conflict of interest to be declared.

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Association between adiposity indicators and cardiorespiratory fitness among rural northeastern Thai adolescents

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ABSTRACT

Introduction: Obesity or high adiposity is known to be associated with various medical consequences, such as diabetes mellitus, hypertension, coronary heart disease and metabolic syndrome. High adiposity and poor cardiorespiratory fitness (CRF) have been found to be related with higher risks of developing cardiovascular disease (CVD). However, previous studies in Asia reported inconsistent findings on the association between obesity or high adiposity, based on various indicators, with impaired CRF. This study investigated the association between adiposity indicators and CRF in terms of maximal oxygen uptake (VO_2 max) in adolescents from rural northeastern Thailand. **Methods:** This study was performed among 486 adolescents aged 14-15 years old in Khon Kaen province, Thailand. Adiposity indicators included body mass index-for-age z-scores (BAZ), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and percent body fat (%BF) based on deuterium dilution technique. **Results:** Male adolescents had higher WHR and VO_2 max than female adolescents, while female adolescents had higher %BF and WHtR. Adolescents who had higher adiposity tended to have lower VO_2 max, especially among females in which the lowest VO_2 max was found in the highest quintile of adiposity indicators, including BAZ, WC, WHtR and %BF. **Conclusion:** Adolescents with higher adiposity tended to have poorer CRF. Based on previous knowledge that both high adiposity and poor CRF may lead to higher risks of developing CVD, this suggests that obese adolescents should be considered and managed at an early age in order to maintain optimal CRF.

Keywords: Adiposity, cardiorespiratory fitness, adolescent

INTRODUCTION

Unhealthy eating habits, physical inactivity and sedentary lifestyle are regarded as important contributors to an increase in obesity prevalence. Obesity is known to be associated with various medical consequences, such as diabetes mellitus, hypertension, coronary heart

disease and metabolic syndrome (Holvoet *et al.*, 2004). Currently, the prevalence of cardiovascular disease (CVD) is increasing and it is the leading cause of mortality and morbidity worldwide. Cardiorespiratory fitness (CRF) and body composition have been found to be related with the risk of CVD, even among children and adolescents (Eisenmann *et*

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al., 2007; Jago *et al.*, 2010). Eisenmann *et al.* (2007) studied the relationship between CRF and fatness with CVD risk score among children and found that both high fatness or high adiposity and low fitness were related with higher CVD risk scores. Similarly, another study reported that both high fatness and low fitness increased cardiometabolic risk factors among children (Jago *et al.*, 2010). Moreover, the relationship between high adiposity and low CRF has been reported in children and adolescents (Jambarsang, Dana & Farzanegi, 2014; Watanabe, Nakadomo & Maeda, 1994; Burns *et al.*, 2013). In Western countries, percent body fat (%BF) was reported to be negatively associated with CRF (Burns *et al.*, 2013; Ramirez-Velez *et al.*, 2017). A study in the Middle Eastern country also reported similar findings - a negative association between body mass index (BMI) and CRF, although BF was not assessed in this study (Jambarsang *et al.*, 2014). However, findings were not consistently significant when BMI was used as an adiposity indicator (Burns *et al.*, 2013; Ramirez-Velez *et al.*, 2017; Mota *et al.*, 2006). Inconsistent findings were also reported among Asian countries. Several studies reported a negative association between adiposity and CRF among children and adolescents based on either anthropometric or BF indicators (Watanabe *et al.*, 1994; Gonzalea-Suarez *et al.*, 2013; Kim *et al.*, 2016).

Inconsistent findings might be due to the variations in adiposity indicators used among the studies. Adiposity indicators namely BMI, %BF, waist circumference (WC) and hip circumference (HC), are accepted globally as indicators of nutritional status in children and adolescents (Chatterjee, Chatterjee & Bandyopadhyay, 2006). It is known that at a certain BMI, %BF varies depending on age, sex and ethnic groups (WHO

Expert Consultation, 2004). Among the various anthropometric adiposity indicators, waist-to-hip-ratio (WHR), a marker of central adiposity, was found to be the best adiposity risk indicator for acute myocardial infarction in most populations worldwide (Yusuf *et al.*, 2005). Waist-to-height-ratio (WHtR), which is another central adiposity indicator, has the advantage of not requiring an age and sex-specific reference table, contrary to WC (Burns *et al.*, 2013). High WHtR has been shown to be related with a higher risk of CVD (Mokha, Srinivasan & DasMahapatra, 2010; Hara *et al.*, 2002).

The evidences above indicate that high adiposity and poor CRF are related with the risk of developing CVD, as high adiposity is related with poor fitness. Since abnormal CVD risks in children or adolescents with high adiposity may not be shown, evidence of a relationship between adiposity and CRF should be ascertained in these groups. The strength of evidence on the negative relationship between adiposity and CRF may help to advocate people in managing or preventing adiposity early in life in order to lessen the risks of CVD later. Although there is a well-known association between body composition and CRF in children and adults (Jambarsang *et al.*, 2014; Watanabe *et al.*, 1994; Burns *et al.*, 2013), studies conducted in the Asian adolescent population are limited and those with the use of various indicators have reported inconsistent findings. Since different adiposity indicators may reflect adiposity differently depending on age, sex and ethnic groups, studies that could strengthen the evidence of a relationship between adiposity and CRF in Asian adolescents are needed.

Hence, this study was designed to evaluate adiposity based on BMI-for-age z-scores (BAZ), WC, WHR, WHtR and %BF, with CRF in terms of maximal

oxygen uptake (VO_2 max) among rural Thai adolescents. Correlations between adiposity indicators and VO_2 max were assessed. We hypothesised that negative relationships between adiposity indicators and CRF would be shown in the adolescent population.

MATERIALS AND METHODS

Study population

The study was performed among adolescents who previously participated in a randomised controlled trial for iron and/or zinc supplementation during infancy from 1998 to 1999, in Khon Kaen province, northeastern region of Thailand (Wasantwisut *et al.*, 2006). 486 adolescents (257 males and 229 females), aged between 14-15 years old voluntarily participated in this study. These adolescents did not have any health conditions, including respiratory tract diseases, physical disabilities, mental problems, or other diseases that affected the assessment of CRF. The required sample size was estimated based on the correlation coefficients (r) of the relationships between %BF and WHtR with CRF ($r=0.261$ and $r=0.241$, respectively) from a previous study (Burns *et al.*, 2013). Sample size estimates of 185 and 218 adolescents were considered as adequate to detect the relationship of interest with a 95.0% power and 0.05 significance level. All procedures were approved by the Mahidol University Central Institutional Review Board (COA. No.2013/008.1501). Written informed consent and assent were obtained from the parents and adolescents prior to the study. The study was registered at ClinicalTrials.gov (NCT01979770).

Anthropometric assessment

Body weight was measured to the nearest 0.1kg with a calibrated digital scale (Tanita, BC-541), while height was

measured to the nearest 0.1cm with a stadiometer. BMI (kg/m^2) was calculated as weight in kilogramme (kg) divided by height in metres squared (m^2). BAZ was calculated and classified based on the 2007 World Health Organization (WHO) growth reference for school-aged children and adolescents (De Onis *et al.*, 2007). All adolescents were in light clothing and without shoes while taking these measurements. WC was taken at the midway between the lowest rib and the iliac crest (Callaway *et al.*, 1988). HC was measured at the widest part of the buttock. All the data were taken in triplicates and the average measurement was used in data analysis. WHR was obtained by dividing WC with HC and WHtR was obtained by dividing WC with height.

Body fat (BF) assessment

BF was estimated from total body water (TBW) assessed by the deuterium dilution technique. A baseline urine sample was collected and the deuterated water containing approximately 0.05g/kg body weight of 99.0 atom % deuterium oxide was administered orally. Three post-dose samples were collected at 3-, 4- and 5-hour after the initial dose was given. All urine samples were analysed for deuterium enrichment using the Isotope Ratio Mass Spectrometry (Sercon Limited, Cheshire, United Kingdom). TBW content was derived using the plateau approach (IAEA, 2009). Fat-free mass (FFM) was calculated from TBW using the Lohman's age appropriate hydration constants. BF (kg) was obtained by subtracting FFM from total body weight and was presented as %BF.

Maximal oxygen uptake (VO_2 max) assessment

VO_2 max is considered to be the gold standard in determining CRF (Wilmore & Costill, 2005; Chatterjee, Chatterjee & Bandyopadhyay, 2005). Nevertheless,

the use of direct methods to measure VO_2 max is limited because of its exhausting and impractical protocols, and requirement of a well-equipped laboratory. However, an earlier study had established the use of Queen's college step test to predict VO_2 max indirectly (Chatterjee, Chatterjee & Bandyopadhyay, 2004).

The Queen's college step test is a physical fitness test that was conducted to measure CRF (McArdle *et al.*, 1972). The step test performed by the individuals involved step up and step down on a bench with a standardised step height of 16.25 inches (41.25cm). The rates (cadence) at 24 steps per minute for males and 22 steps for females were set by a metronome. The test began after a brief demonstration and practice period. Adolescents were instructed to perform the steps using a four-step cadence, "up-up-down-down" continuously for 3 min. They had to maintain their determined stepping rhythm during the test and stop immediately on completion of the test. After that, they were required to remain standing and a heart rate monitor was used (Polar FT4, Kempele, Finland) to measure their heart rates at the 20th second post-test. VO_2 max was calculated using the McArdle's equations (McArdle *et al.*, 1972):

$$\text{Male: } \text{VO}_2 \text{ max (mL/kg/min)} = 111.30 - 0.42 \times \text{heart rate (bpm)}$$

$$\text{Female: } \text{VO}_2 \text{ max (mL/kg/min)} = 65.81 - 0.1847 \times \text{heart rate (bpm)}$$

Those who were fit would have a higher VO_2 max and would be able to perform exercises with higher intensity for a longer period of time than unfit subjects.

Statistical analysis

Data were checked for normality and descriptive statistics were presented accordingly. Comparisons between male and female adolescents were performed using the independent

sample *t*-test or Mann-Whitney U test. Spearman's correlation was used to determine the correlation between VO_2 max and adiposity indicators. Adiposity indicators including BAZ, WC, WHR, WHtR and %BF were categorised into quintiles. One-way analysis of variance (ANOVA) was used to test the differences of VO_2 max among quintiles of adiposity indicators and for linear trends across quintiles. All statistical analyses were performed using SPSS for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). A *p*-value of <0.05 was considered statistically significant.

RESULTS

Characteristics of participating adolescents are presented in Table 1. Male adolescents have higher WHR and VO_2 max than female adolescents (0.78 vs. 0.76 and 49.6mL/kg/min vs. 35.2mL/kg/min, respectively). BMI, HC, WHtR and %BF were higher in females than males (19.0kg/m² vs. 18.5kg/m², 86.3cm vs. 84.0cm and 26.6% vs. 15.8%, respectively), while BAZ and WC were not significantly different in both genders.

Table 2 shows the correlation between VO_2 max and adiposity indicators (BAZ, WC, WHR, WHtR and %BF). VO_2 max had a significant, negative correlation with %BF in both male and female adolescents ($r=-0.17$, $p=0.009$ and $r=-0.38$, $p=0.000$, respectively). In female adolescents, VO_2 max was also significantly negatively correlated with BAZ, WC, WHR and WHtR ($r=-0.24$, $p=0.000$, $r=-0.24$, $p=0.000$, $r=-0.14$, $p=0.040$ and $r=-0.23$, $p=0.000$, respectively). For illustrative purposes, the negative relationships between %BF and VO_2 max among males and females are shown in Figure 1.

Mean VO_2 max by quintiles of adiposity indicators in males and females are presented in Table 3. Among males, there were no differences in VO_2 max by

Table 1. Descriptive characteristics of study participants

Characteristics	n (%)		Mean±SD		Median (P25, P75)		p value
	Male (n=257)	Female (n=229)	Male (n=257)	Female (n=229)	Male (n=257)	Female (n=229)	
Age (years)			14.8±0.3	14.7±0.3			0.114
Height (cm)			164.5±6.8	155.3±5.4			0.000
Weight (kg)					50.2 (45.4, 56.5)	46.2 (41.9, 50.8)	0.000
BMI (kg/m ²)					18.5 (17.1, 20.2)	19.0 (17.4, 20.8)	0.038
BAZ					-0.47 (-1.20, 0.19)	-0.39 (-1.08, 0.25)	0.223
Nutritional status							
Thinness (BAZ<-2SD)	20 (7.8)	14 (6.1)					
Normal (-2SD≤BAZ≤1SD)	214 (83.3)	194 (84.7)					
Overweight (1SD<BAZ≤2SD)	15 (5.8)	16 (7.0)					
Obesity (BAZ>2SD)	8 (3.1)	5 (2.2)					
WC (cm)					65.4 (62.7, 69.3)	65.2 (62.7, 68.9)	0.516
HC (cm)					84.0 (80.6, 88.4)	86.3 (83.3, 89.6)	0.000
WHR					0.78 (0.76, 0.81)	0.76 (0.74, 0.79)	0.000
WHtR					0.40 (0.38, 0.42)	0.42 (0.40, 0.45)	0.000
%BF			15.8±6.3 (n=234)	26.6±6.3 (n=222)			0.000
VO ₂ max (mL/kg/min)					49.6 (45.0, 54.2)	35.2 (33.7, 37.2)	0.000

BMI: body mass index; BAZ: BMI-for-age Z scores; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat; VO₂ max: maximal oxygen uptake; SD: standard deviation

Table 2. Correlation coefficients (*r*) between VO₂ max (mL/kg/min) and adiposity indicators

Adiposity indicator	<i>r</i>	<i>p</i> -value	<i>n</i>
Male			
BAZ	-0.07	0.274	257
WC (cm)	-0.02	0.760	257
WHR	0.01	0.851	257
WHtR	-0.04	0.499	257
%BF	-0.17	0.009	234
Female			
BAZ	-0.24	0.000	229
WC (cm)	-0.24	0.000	229
WHR	-0.14	0.040	229
WHtR	-0.23	0.000	229
%BF	-0.38	0.000	222

BAZ: BMI-for-age z-scores; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat

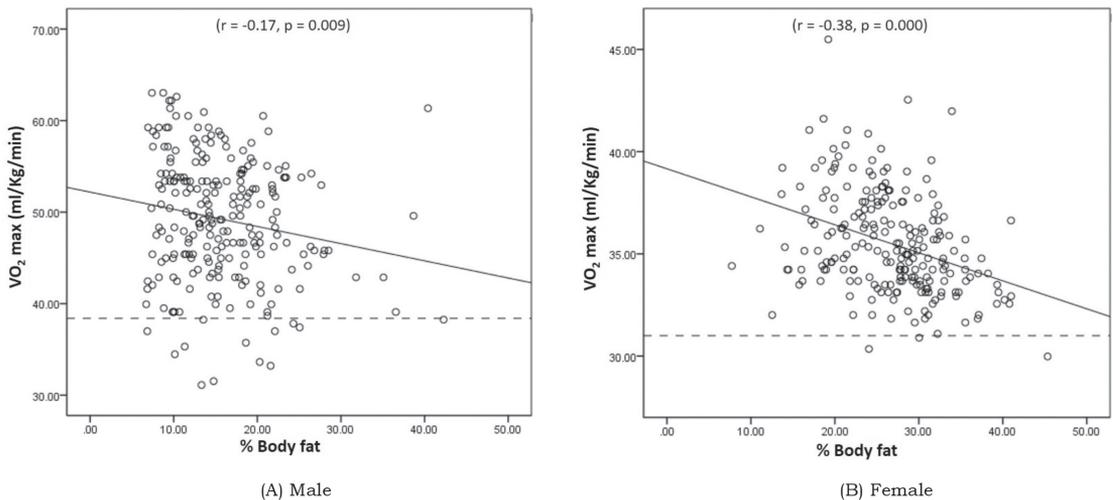


Figure 1. Negative relationship between %BF and VO₂ max (mL/kg/min) in male (A) and female (B) adolescents

quintiles of BAZ, WC, WHR and WHtR. However, there was a significant trend of decreasing VO₂ max with increasing %BF quintiles (*p* for trend <0.05). Among females, VO₂ max significantly declined with increasing quintiles of BAZ, WC, WHtR and %BF (*p* for trend <0.05). However, this relationship did not show significance for the quintiles of WHR.

DISCUSSION

Overall, this study showed that adolescents who had higher adiposity indicators tended to have lower CRF, especially among females. However, this relationship was not consistent among all adiposity indicators in male adolescents. Nonetheless, male

Table 3. VO₂ max (mL/kg/min)[†] by quintiles of adiposity indicators

Adiposity indicator	Mean±SD					p-trend
	Q1	Q2	Q3	Q4	Q5	
Male						
VO ₂ max by BAZ quintiles	49.4±6.1	49.6±7.6	49.7±7.5	50.9±5.6	47.5±6.4	0.421
VO ₂ max by WC quintiles	48.9±5.4	49.4±8.0	49.9±7.2	50.7±5.9	48.1±6.7	0.950
VO ₂ max by WHR quintiles	50.2±7.1	47.4±6.7	49.5±6.5	50.8±6.6	49.1±6.4	0.681
VO ₂ max by WHtR quintiles	50.3±6.7	48.6±7.7	48.7±6.3	51.0±5.9	48.5±6.7	0.691
VO ₂ max by %BF quintiles	51.2±7.5	49.5±7.0	49.4±6.4	48.8±5.6	47.2±6.8	0.006
Female						
VO ₂ max by BAZ quintiles	36.1±2.5	36.0±2.8	35.8±3.0	35.8±2.1	34.2±2.1	0.001
VO ₂ max by WC quintiles	35.9±2.5	35.9±2.3	36.7±3.3	35.3±2.1	34.2±2.2	0.001
VO ₂ max by WHR quintiles	35.5±2.1	36.2±2.9	36.1±3.0	35.5±2.2	34.7±2.5	0.055
VO ₂ max by WHtR quintiles	35.8±2.3	36.1±2.9	36.0±2.2	35.9±2.9	34.1±2.1	0.002
VO ₂ max by %BF quintiles	36.7±2.7	36.2±2.5	35.6±2.1	34.8±2.3	34.3±2.1	0.000

VO₂ max: maximal oxygen uptake; BAZ: BMI-for-age z-scores; WC: waist circumference;

WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat; SD: standard deviation

adolescents who had higher %BF tended to have lower CRF. Our findings were not entirely in agreement with previous studies conducted in Asia (Watanabe *et al.*, 1994; Gonzalez-Suarez *et al.*, 2013; Kim *et al.*, 2016). Similar negative associations of adiposity and CRF in both males and females were reported earlier in a study among Japanese children and adolescents, when adiposity was assessed as %BF and CRF was assessed as VO₂ max (Watanabe *et al.*, 1994). However, the sample size in that study was quite small ($N=37$) and it might be due to the limitation of the underwater weighing technique used for body composition assessment. In comparison with a study in the Philippines (Gonzalez-Suarez *et al.*, 2013), our study population was older and had lower proportion of overweight and obesity. Hence, this may explain the discrepancy between our findings and that of theirs. We reported significantly negative associations of BAZ, WC, WHR and WHtR with CRF only in female adolescents, while

they reported significantly negative associations between BMI and WC with CRF in both sexes. A study by Kim *et al.* (2016) in South Korea included both boys and girls aged 9-10 years old, as well as boys of older age (12-13 years old) only. As the proportion of overweight and obesity was quite high compared to our study (28.0% vs. 8.9%), this might explain the significant, negative associations between anthropometric adiposity indicators with CRF reported in their study, while there were no such significant associations among males in our study.

A study conducted among US children also found that BMI, WC and WHtR were not associated with CRF, while %BF was significantly associated with CRF (Burns *et al.*, 2013). BF might be more appropriate to reflect adiposity among male adolescents compared with adiposity indicators developed from anthropometric measures such as BMI, WC, WHR or WHtR. A longitudinal study among healthy Caucasian

children indicated the differences in the contribution of BF and FFM to BMI increase in male and female adolescents when they reached 13 years old of age (Maynard *et al.*, 2001; Kirchengast, 2010). Although BMI increased in both sexes as age increased, however, the major contribution to BMI increase was total BF among females, while FFM among males. This may imply that high BMI or high levels of other anthropometric adiposity indicators may not be related with high BF in male adolescents, thus consequently resulting in no associations between anthropometric adiposity indicators and CRF.

The strengths of this study were that we used multiple indicators of adiposity. In this study, BF was assessed using the deuterium dilution technique. Although many methods exist to measure BF, some methods may be expensive, expertise and appropriate equation-required, or not field applicable (IAEA, 2009). The deuterium dilution technique is an accurate and suitable method for population-based studies. The use of BF as an adiposity indicator provided more reliable and consistent evidence on the relationship between adiposity and CRF compared with other proxy adiposity indicators developed from anthropometric measures.

We used VO_2 max to reflect CRF. CRF can be assessed by various ergometer exercise techniques such as walking on treadmill, cycling, swimming and bench stepping. In this study, CRF was estimated using the Queen's college step test because it is one of the common physical fitness tests feasible for field application. This technique is usually performed at a fixed rhythm on a bench having a fixed height (McArdle *et al.*, 1972). A previous study suggested that local muscular fatigue may occur before a true assessment of aerobic capacity if a step is too high. Consequently, the

test may be more of a measurement of muscular endurance of the legs than of aerobic capacity (Shamsi *et al.*, 2011). Thus, the height of the step bench should be adjusted to the participant's stature and this may decrease the inter-individual variability in oxygen cost and heart rate during a task and, as such, may produce a valid prediction of VO_2 max (Shamsi *et al.*, 2011; Shahnawaz, 1978). However, a study that assessed aerobic capacity based on a fixed height and adjusted height of the bench (90° knee joint angle) confirmed no significant difference in the aerobic capacity between these two levels of bench height (Ashley, Smith & Reneau, 1997).

In addition to the height of the bench, accuracy of the heart rate should be considered when measuring VO_2 max. Pulse rate counting might lead to an underestimation of post-exercise heart rate (John, Sforzo & Swenson, 2007). Hence, we used an automatic heart rate monitor, which administration was simple and accurate.

This study had some limitations in which only young adolescents with a narrow age range (14-15 years old) were included and the prevalence of obesity was rather low (male=3.1% and female=2.2%) among the study population. These limitations may restrict the generalisation of the findings.

CONCLUSION

Adolescents with higher adiposity tended to have lower CRF in this study. Especially among female adolescents, the highest quintile of adiposity indicators, e.g. %BF and BAZ resulted in the lowest VO_2 max. This may suggest that adolescents who have higher %BF have lesser physical fitness and therefore, cannot perform well in physical activities, especially in a CRF task. In order to maintain optimal CRF, which may consequently lessen the risk of CVD, obesity in individuals should be considered and managed at

an early age. Future research is needed to develop suggested cut-off points for adiposity indicators that may contribute to low levels of VO_2 max and to assess the extent to which high adiposity and low level of VO_2 max during adolescence contribute to the higher risks of developing CVD later in life.

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Authors' contributions

WS, designed the study, collected data, contributed to statistical analysis, drafted the manuscript; TP, designed the study, collected data, drafted the manuscript; KJ, designed and supervised total body water sample analysis; PW, designed the study, critically revised the manuscript; SG, collected data, contributed to statistical analysis, drafted the manuscript; WW, contributed to statistical analysis; all authors read and gave final approval of the manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

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Microwave cooking enhances glycaemic potential of rice: An *in vitro* study

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ABSTRACT

Introduction: Rice is the principle staple and energy source for nearly half the world's population and has significant nutrition and health implications. Most rice varieties are considered high glycaemic index (GI) foods. With rice being a major contributor to the glycaemic load in Asian populations, there is increasing concern of its impact on the development of type 2 diabetes. Devising ways to reduce the glycaemic impact of rice is therefore imperative. Rice is cooked in a variety of ways, such as over an open fire, electric cooker or microwave. We evaluated the impact of the electric cooker and microwave cooking methods on starch digestibility in a variety of rice commonly consumed in Asia. **Methods:** Nine rice varieties of varying GIs were cooked in an electric cooker and microwave oven, and the starch digestibility of cooked rice measured using an *in vitro* digestion method. **Results:** High GI white rice (WR) had reduced starch digestibility after microwave cooking compared to electric cooker ($p < 0.05$). There was a significant reduction in incremental area under the curves (iAUC) and rapidly digestible starch of WR cooked using microwave rather than electric cooker ($p < 0.05$). Interestingly, even for low GI rice varieties such as idly rice and extra long basmati rice, microwaving increased slowly digestible starch. **Conclusion:** The results provide indicative data that the glycaemic impact of rice can be reduced when cooked using a microwave oven. These observations have nutritional implications that need to be substantiated using *in vivo* studies. Microwaving may provide a simple method of reducing the postprandial glycaemia of high GI rice.

Keywords: Cooking method, microwave cooking, rice, starch digestibility, glycaemic index

INTRODUCTION

Rice (*Oryza sativa*) is an important staple food of an estimated 3.5 billion people worldwide, with more than 90% of rice being consumed in Asia (Mohanty, 2013).

The major component of rice is starch, which provides substantial energy for human needs. It also has a high protein digestibility, biological value and protein efficiency ratio owing to the greater concentration of lysine among all the

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cereals (Eggum, 1979). The glycaemic index (GI) and glycaemic load (GL) are measures used to estimate and rank the postprandial glycaemic response to carbohydrate-containing foods. More specifically, the GI is a simple way of characterising carbohydrates based on their impact on postprandial glycaemic response (Jenkins *et al.*, 1981a). Carbohydrates with a low GI value (<55) are more slowly digested, absorbed and metabolised, and lead to a slower rise in blood glucose than those higher in GI values (Jenkins *et al.*, 1981b). Using GI, GL can be calculated by multiplying the food's specific GI with the consumed quantity of carbohydrate in that food. Recent epidemiological studies suggest that rice is potentially a significant contributor to the diabetes incidence, especially in Asian communities where rice is a major contributor to GL (Hu *et al.*, 2012). In several studies, rice has been reported to be a high GI food (>70) (Jenkins *et al.*, 1981a, Miller, Pang & Bramall, 1992). The rising rates of diabetes in Asia coupled with the excessive consumption of high GI rice means that there is a need to find ways to reduce the glycaemic impact of rice (Zheng, Ley & Hu, 2018). While there are many processed rice products in the market today (Juliano, 1993), rice is primarily consumed in the form of cooked grains. A recent extensive review has shown that one of the major factors affecting digestibility of rice is the method of cooking (Kaur, Ranawana & Henry, 2016). During cooking, changes occur in the rice structure, which in turn alter the nutritional characteristics, including starch digestibility. Some studies have also reported that cooking methods can affect the starch digestibility of rice. The nutritional composition of rice varieties may be influenced by cooking methods depending upon techniques and

conditions including temperature, time and moisture (Han, Lee & Rhee, 2008; Reed *et al.*, 2013). For centuries, rice has been cooked over an open flame (or other sources of heat) with water, by a rapid/gentle boil method (Bhattacharya, 2011). The development of the electric rice cooker automated the process of cooking rice by mechanically or electronically controlling heat and timing. The electric rice cooker was invented and was first introduced by Toshiba Japan in 1955. With the first introduction and the availability of power grids to domestic users, the use of electric cooker became widespread (Ito, 2017). With an electric rice cooker, the user's involvement in cooking rice is reduced to simply measuring the rice, preparing the rice properly and using the correct amount of water. Once the rice cooker is set to cook, no further attention will be needed during the cooking duration. However, unlike an electric rice cooker that does not necessarily speed up the cooking process (cooking time of up to 30 min), microwave ovens do reduce cooking time (cooking time of ≤ 15 min). In recent years, there has been an increased ownership of domestic microwave ovens, which has revolutionised the way we cook rice. In microwave cooking, foods are cooked by frictional heat produced by the action of microwaves on water molecules, causing them to vibrate at high speed (Khatoon & Prakash, 2006).

The present study is to investigate the effect of cooking methods on starch digestibility of rice. Our aim was to investigate the glycaemic impact of rice cooked using an electric cooker and a microwave oven, assessed using an *in vitro* starch digestion method. In addition to the commonly consumed white rice, we also compared eight other rice varieties with different GIs, chosen based on their popularity in Asia.

MATERIALS AND METHODS

Rice samples

All rice samples were purchased in Singapore. The nine rice varieties chosen were Thai Hom Mali Jasmine white rice (WR), premium Calrose rice (CR), Kangaroo Australian low GI rice (LGR), iddly rice (IR), fresh brown Jasmine rice (BJR), extra long Basmati rice (LBR), premium Thai red rice (TRR), white glutinous rice (WGR) and black glutinous rice (BGR). The proximate nutrient composition and GI of these rice samples are provided in Table 2. The GI of rice samples were also obtained from our previous work and from the literature (Table 2). The rice variety, abbreviation, country of known origin, pre-cooking preparation and cooking conditions are presented in Table 1.

Chemicals and reagents

Alpha-amylase from porcine pancreas type VI-B, pepsin from porcine gastric mucosa powder, maleic acid, sodium hydroxide (NaOH), bile extracts porcine, amyloglucosidase from *Aspergillus niger*, pancreatin from porcine pancreas, sodium acetate trihydrate, 3,5-dinitrosalicylic acid and potassium sodium tartrate were purchased from Sigma-Aldrich (MO, USA). Hydrochloric acid (HCl), ethanol and acetic acid were obtained from Merck (Darmstadt, Germany). Glucose was purchased from Kento Chemical Co., Inc. (Tokyo, Japan).

Preparation and cooking of rice samples

The nine rice samples were cooked using an electric rice cooker and a microwave oven (R-398F, SHARP CORP, Japan). For each cooking method and rice variety, the optimum time and procedures were established before the actual experimental testing (Table 2). Rice were cooked until no white core remained in the rice kernels (Lum, 2017).

For electric rice cooking, WR, CR, LGR, IR and LBR were washed and drained thrice with water and then placed into the electric rice cooker with a rice:water ratio of 1:1.4 [weight/volume (w/v)]. A rice water ratio of 1:2 (w/v) was used for BJR or TRR. WGR and BGR were soaked for 30 min and placed into the rice cooker by rice:water ratio of 1:1.4 (w/v) and 1:2 (w/v), respectively. Rice was wrapped in aluminium foils to further keep warm until ready for digestion. Digestion of samples began within 20 min after cooking.

For microwave cooking, a rice:water ratio of 1:1.8 (w/v) was used for the cooking of WR, CR, LGR, IR, LBR and WGR. Prior to microwaving, these rice samples were washed and drained thrice with water. BJR, TRR and BGR were cooked with a rice:water ratio of 1:2.5 (w/v) (Table 1). The cooked rice was left at room temperature (25°C) until analysis. Rice was wrapped in aluminium foils to further keep warm until ready for digestion. Digestion of samples began within 20 min after cooking.

In vitro digestion of rice

The glycaemic potential of the cooked rice samples were assessed using a pre-validated *in vitro* starch digestibility model, that mimics the human gastrointestinal digestion (Mishra & Monro, 2009, Monro *et al.*, 2010). This method has been shown to provide accurate, indicative data on the *in vivo* glycaemic response.

Rice samples (2.5g) with 30mL of distilled water was digested in specimen pots and inserted into a 12-position aluminum block placed in a circulating water bath maintained at 37°C with stirring at 130rpm. After stirring for 30 min, the oral phase was initiated by the addition of 100µL of 10% α-amylase (≥10 units/mg solid) in distilled water for 1 min. Then, 200µL of 1 M HCL was added to the samples in quick succession

Table 1. Rice variety, abbreviation, country of known origin, pre-cooking preparation and cooking conditions

Rice variety	Abbreviation	Brand/ Country	Pre-cooking preparation	Cooking condition and time	
				Microwave oven (MO)	Electric rice cooker (EC)
Thai Hom Mali premium quality fragrant rice (Jasmine white rice)	WR	Double FP, Bangkok, Co. Ltd, Thailand	Wash rice thrice (MO)	500 w for 7 min	Cooking time 10 min
White glutinous rice	WGR	Fairprice Brand, Singapore	Soak for 20 min (MO) Soak for 30 min (EC)	500 w for 6 min and then stirring 500 w for 5 min	Cooking time 8 min
Premium Calrose rice	CR	Kangaroo Brand, Australia	Wash rice thrice (EC)	500 w for 10 min	Cooking time 12 min
Brown Jasmine rice	BJR	Golden Eagle, Thailand	Soak for 10 min (MO)	500 w for 10 min and then stirring 500 w for 6 min	Cooking time 18 min
Iddly rice	IR	Ambikas, India		500 w for 10 min	Cooking time 14 min
Low GI rice	LGR	Kangaroo Brand, Australia		500 w for 8 min	Cooking time 10 min
Extra long Basmati rice	LBR	Monsoon, India		500 w for 9 min	Cooking time 11 min
Premium Thai red rice	TRR	PadyKing, Thailand	Soak for 10 min (MV)	500 w for 15 min and then stirring 500 w for 2 min	Cooking time 20 min
Black glutinous rice	BGR	Fairprice Brand, Singapore	Soak for 30 min (MV and EC)	500 w for 15 min and then stirring 500 w for 5 min	Cooking time 19 min

Table 2. Proximate composition of rice samples

Types of rice	Glycaemic index (GI)	Composition (% m/m)			
		Total carbohydrate	Available carbohydrate	Total protein	Total fat
Thai Hom Mali Jasmine white rice (WR)	91	81.26	76.55	6.94	0.38
White glutinous rice (WGR)	93	81.80	76.85	7.25	0.18
Premium Calrose rice (CR)	83	78.79	73.67	7.46	0.80
Brown Jasmine rice (BJR)	74	76.59	68.59	7.80	2.91
Iddly rice (IR)	38	81.16	73.96	8.05	0.57
Low GI rice (LGR)	54	80.60	70.72	7.54	0.65
Extra long Basmati rice (LBR)	52	78.96	71.04	9.18	1.27
Premium Thai red rice (TRR)	55	75.78	65.64	8.62	2.66
Black glutinous rice (BGR)	42	72.86	66.84	10.71	2.09

to adjust it to pH 2.5 (± 0.2), measured by the pH meter (SevenCompact™, METTLER TOLEDO®, OH, USA). Gastric phase was then initiated by the addition of 1 mL of 10% pepsin (≥ 250 units/mg solid) dissolved in 0.05 M HCl. The mixture was continuously stirred at 37°C for 30 min to complete the gastric digestion phase. After which, 2mL of 1 M NaHCO₃ and 5mL of 0.2 M maleate buffer (pH 6) were added into the mixture to neutralise gastric HCl. Five millilitres of 10% bile extract solution in distilled water was added to the mixture and then distilled water was filled into the pots to adjust the volume to 55mL. After holding for 15 min to reach 37°C, the pancreatic phase was started by adding 100µL of amyloglucosidase (≥ 260 U/mL, aqueous solution) and 1mL of 5% pancreatin in 0.2M maleate buffer. An aliquot of 250µL from baseline, the end of oral and gastric phase, and at 20, 60, 90, 120 and 180 min from the start of pancreatic phase was drawn and transferred into tubes containing 1mL of ethanol to end the enzymatic digestion (Monro *et al.*, 2010, Mishra & Monro, 2009).

Analysis of reducing sugars released during *in vitro* digestion

Reducing sugars released from the rice samples during *in vitro* digestion (ethanolic digesta) was measured by Dinitrosalicylic acid (DNS) colourimetric method (Englyst & Hudson, 1987). The ethanolic digesta samples were centrifuged at 1000rpm for 10 min. Fifty microlitres of aliquots from the supernatant were removed and mixed with 250µL of 0.1M acetate buffer (pH 5.2) containing 1% amyloglucosidase (≥ 260 U/mL, aqueous solution). After incubation at 37°C for 10 min, 750µL of DNS mixture (0.5mg/mL of glucose: 4 M NaOH:DNS reagent mixed in ratio at 1:1:5) was added. The mixture was heated at 95-100°C for 15 min and then 4mL of distilled water was added to each sample. After cooling at room temperature, absorbance was read at 530nm by a microplate reader (Infinite® 200 PRO, Tecan Trading AG, Switzerland). Glucose (10mg/mL) and distilled water were used as standard and blank, respectively. The results were expressed as mg/mL of glucose.

Determination of rapidly digestible starch, slowly digestible starch and undigested starch

Rapidly digestible starch (RDS) was calculated as the amount of digested starch within the initial 20 min (G20) after the start of pancreatic phase (Englyst *et al.*, 1999). Slowly digestible starch (SDS) was defined as the amount of digested starch between 20 and 120 min (G120). Undigested starch (US) was considered as the amount that was not digested within 120 min. Each fraction was calculated as follows: $RDS=(G20-\text{Free Glucose})\times 0.9$; $SDS=(G120-G20)\times 0.9$; $US=(G180-120)\times 0.9$. The conversion factor is 0.9 from glucose to starch (Englyst *et al.*, 1999).

Statistical analysis

All experiments were carried out in triplicate. The data were presented as mean \pm standard error of mean (SEM). The comparisons between samples at each individual time point were analysed by one-way analysis of variance (ANOVA) with Duncan's multiple comparison test (SPSS version 17; SPSS Inc., IL, USA). Differences in the incremental area under the glucose curves (iAUC) and amount of RDS and SDS between the samples were determined by one-way ANOVA with Duncan's multiple comparison test. In addition, independent *t*-test was used to analyse iAUC and amounts of RDS, SDS and US for electric cooked and microwave cooked rice samples. Statistical significance was set at $p<0.05$.

RESULTS

The starch digestion curves of rice cooked by an electric cooker (A) and microwave oven (B) are illustrated in Figure 1. WR cooked in an electric cooker had a significantly higher rate of glucose release compared to microwave cooking for all phases of the *in vitro* model ($p<0.05$). For electric cooking, WR

had the highest amount of incremental glucose concentration during the time of digestion. The incremental glucose concentrations of WR were significantly higher at oral phase and at 60, 90, 120 and 180 min of intestinal phase compared to all the other rice varieties ($p<0.05$). Figure 2 displays the iAUC for glucose release of all rice varieties for both cooking methods. The iAUC for WR cooked using electric cooker was 1.4 times higher than microwave cooking ($p<0.05$). Although there were no significant differences for the other rice varieties, it was noteworthy that microwaving high GI varieties such as CR, WGR and BJR showed reduction in iAUCs (Figure 2). Furthermore, low GI rice varieties, with the exception of IR, also saw reductions in iAUC when microwave cooking was applied (Figure 2). WR cooked in a microwave oven showed a significant decrease in RDS compared to cooking in an electric cooker (23.5g vs 34.6g/100g) ($p<0.05$) (Figure 3). There was an overall trend showing higher RDS values for high GI rice varieties (except BJR) compared to the low GI rice varieties, irrespective of cooking method (Figure 3). BJR showed the highest quantity of undigested starch when microwaved ($p<0.05$) (Figure 3). Both BGR and TRR had no differences in quantities for each starch fraction (RDS, SDS, US), irrespective of cooking methods. Both LBR and IR had significantly higher quantities of SDS when microwaved compared to electric cooking (LBR: 28.8 vs 16.4g/100g and IR: 26.8g vs 15.3 g/100g) ($p<0.05$).

DISCUSSION

Several studies have investigated the digestibility of rice cooked using various cooking methods (Khatoun *et al.*, 2006; Lee *et al.*, 2005; Li *et al.*, 2014; Rashmi & Urooj, 2003; Chiu & Stewart, 2013). To our knowledge, this is the first to

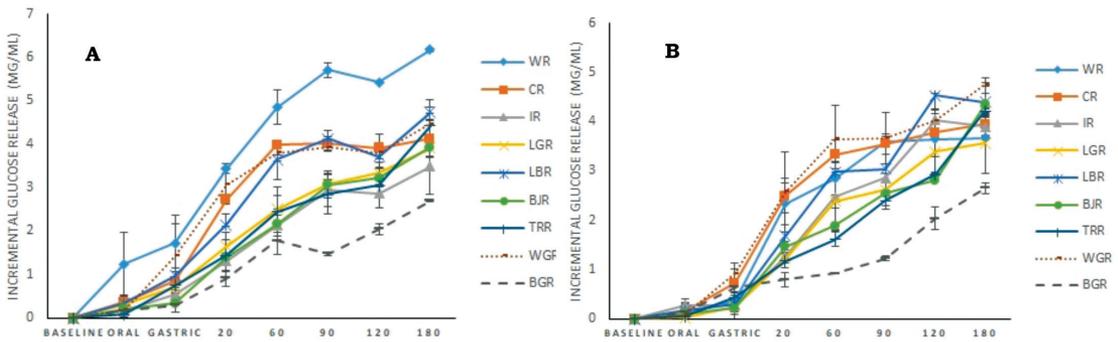


Figure 1. The incremental glucose released from rice varieties cooked using (A) an electric cooker and (B) microwave oven during *in vitro* digestibility. Results expressed as mean±SEM

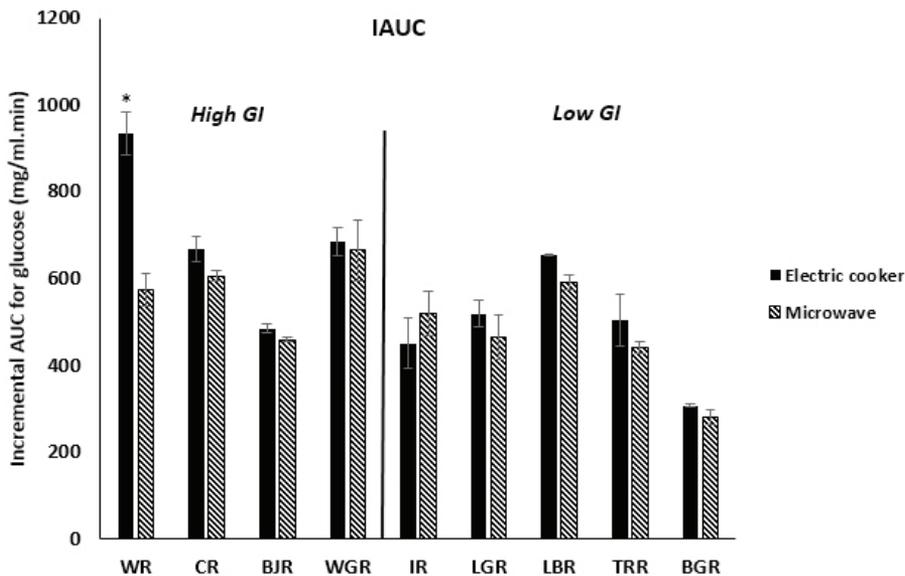


Figure 2. Incremental area under the curve (iAUC) for glucose release of rice varieties cooked using an electric cooker and a microwave oven. Results expressed as mean±SEM.

*Mean values were significantly different between electric cooker and microwave cooking ($p < 0.05$)

examine starch digestibility of a range of low and high GI rice consumed in this part of Asia, which were cooked using both an electric cooker and a microwave oven.

Starch digestibility

WR cooked in a microwave oven had a distinctly slower rate of glucose release compared to electric rice cooking. There

was also a small reduction in starch digestibility of other rice varieties (except for IR) when microwaving was applied compared to electric cooking. Both methods of cooking had a cooking temperature of 100°C, however, the time to reach the boiling temperature was much shorter for microwave cooking (4 min and 41 seconds), versus electric cooking (5 min 22 seconds). The disrupted starch

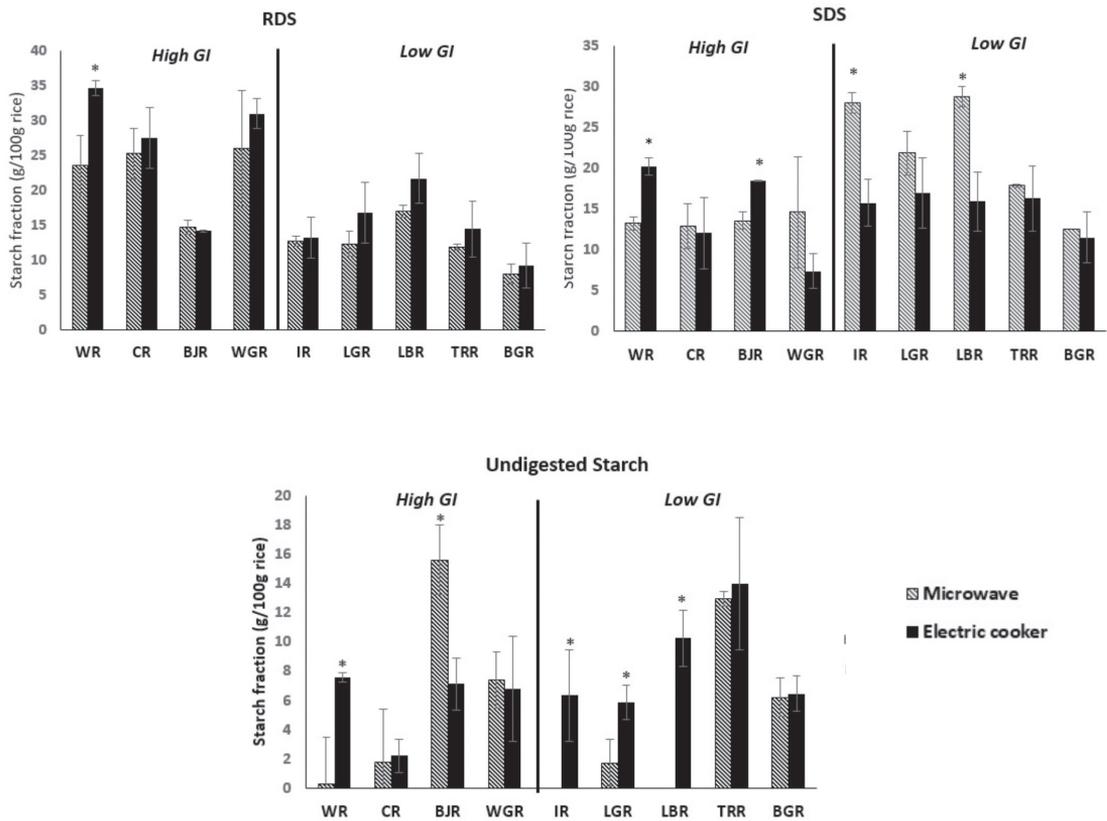


Figure 3. RDS, SDS and US of rice varieties cooked by electric cooker and microwave oven. Results expressed as mean±SEM.

*Mean values were significantly different between electric cooker and microwave cooking ($p < 0.05$)

structure during gelatinisation makes it more accessible to digestive enzymatic degradation and the glycaemic impact of the starch rises (Holm *et al.*, 1988). Microwave cooking has been reported to generate less dispersed gelatinised starch than conventional cooking of starch products, thereby altering the digestibility of starch (Yiu, Weisz & Wood, 1991; Sánchez-Pardo *et al.*, 2007). It has also been shown that the chemical bonds, chemical groups, skeleton, and the way that rice starch are connected with each other are not destroyed by microwave treatment as compared to conventional heating methods (Fan *et al.*, 2012). Moreover, the shorter cooking

time involved with microwaving, results in a reduction in the degree of starch gelatinisation. Another point to note was that the rice to water ratio required for cooking rice using the electric cooker was higher than the microwave oven, which could contribute to increased starch gelatinisation (with the exception of BJR, TRR and BGR which required more water to be completely cooked with microwave oven cooking). This finding is one that is very important, especially for the cooking of white rice, which is a high GI staple commonly consumed in Asia. Microwaving white rice may reduce its glycaemic impact.

RDS, SDS and US

It is well recognised that starch can be classified based on its rate of glucose release and its absorption in the gastrointestinal tract, where they can be classified into RDS, SDS and US (Englyst, Kingman & Cummings, 1992). The RDS content in food is a reflection of the amount of readily digestible starch that is largely accountable for the short-term postprandial glycaemic response, whilst SDS represents the slowly digested starch fraction that produces a low and protracted glycaemic response (Englyst *et al.*, 1992; Englyst *et al.*, 1999). US, or resistant starch, is not digested by carbohydrate digestive enzymes in the small intestine. Cooking WR using the electric cooker produced higher RDS and increased US, which was also observed in a study by Chung and team, where this finding was attributed to the amylose content of white rice (Chung *et al.*, 2010). Microwave cooking had the ability to reduce RDS in WR and slow down the rate of digestibility. This has a beneficial role in reducing the glycaemic impact of high RDS-containing foods such as white rice by producing a slower release of glucose. There was an overall trend of generally higher RDS values for the high GI rice varieties (except BJR) compared to the low GI rice varieties, irrespective of cooking methods. Using an electric cooker, BJR had the longest cooking time compared to other high GI rice varieties. The cooking time primarily determines the extent of starch gelatinisation and as a consequence, the digestibility of rice (Ranawana *et al.*, 2009). Interestingly, BJR produced the largest amount of US (resistant starch) when cooked in the microwave oven. Although BJR is a high GI rice (lower amylose content), with a GI of 74, the starch present in BJR may not be as susceptible to enzymatic hydrolysis as compared to the starch present in WR, WGR and CR. A review by Touttounji *et*

al. (2019) pointed out that even though the starch digestibility of rice is primarily attributed to the amylose content, but the amylopectin fine structure can also play a contributory role. The long chain amylopectin which mimics the structure, and therefore the function of amylose, can also increase resistant starch and reduce the digestibility of rice (Butardo *et al.*, 2017). The increased formation of undigested starch with BJR after microwave cooking could possibly be due to the formation of resistant starch after the cooking process (resistant starch type III), formed in part due to the retrogradation of amylose (Guillén, Oria & Salvador, 2018) and the presence of polyphenols in BJR that could bind with starch molecules (Panlasigui & Thompson, 2006). Rice cooked in a microwave oven has been reported to have a lower RDS content than autoclaved and parboiled rice (Niba, 2003). Microwave processed starches have been shown to have a higher SDS level and a lower digestion rate, which was also observed in our study (Niba, 2003). This *in vitro* observation has potential nutritional implications especially for white rice, which is a very high GI food that causes sharp rises in blood glucose. Both BGR and TRR had no differences in their quantities for each starch fraction (RDS, SDS, US), irrespective of cooking methods. The presence of dietary fibre, bran, anthocyanins and other phytochemicals act as inhibitors to enzymatic digestion. The dietary fibre-rich bran fraction can act as a barrier to digestive enzyme activity, thereby reducing starch digestibility (Tian, Nakamura & Kayahara, 2004, Panlasigui & Thompson, 2006). There was an increase in SDS for LBR when microwaved compared to electrically cooked. An *in vivo* study on LBR also showed a reduction in glycaemic response when cooked in a microwave compared to cooking in a rice cooker

(Gunathilaka & Ekanayake, 2015). IR, which is a parboiled rice, is considered to be a slow digesting product and from our findings, it had the highest SDS quantity with microwaving compared to electric cooking. There was also no US remaining with microwaving IR, which makes it appear to be also a very digestible food. This is possibly due to parboiled rice being relatively low in amylose (13.1%) and being already semi-cooked (soaked, steamed and dried during parboiling operation) (Dhital *et al.*, 2015). Parboiled rice has also been shown to have a very low pasting property due to its granules already being gelatinised (amylose leached out) during the parboiling process and there is no further swelling of the starch granules (Hermansson & Svegmarm, 1996).

Comparing low and high GI cooked rice varieties

All high GI and low GI rice varieties (except IR), had reduced iAUCs when microwave cooking was applied compared to the electric cooker. Although this reduction in iAUC was not significant, except for WR, this pattern of reduced iAUCs may have important nutritional implications. In addition, high proportions of SDS and lower RDS values were observed with the low GI rice varieties when microwave cooking was applied compared to electric cooking, but this trend was not observed with the high GI rice varieties. The application of microwave cooking indeed influenced the nutritional quality of low and high GI rice varieties, even though a significant difference was observed only with white rice. Previous studies on rice starch digestibility led to the conclusion that rice should generally be classified as a high GI/glycaemic response food (Miller *et al.*, 1992, Jenkins *et al.*, 1981a). In contrast, a study by Frei, Siddhuraju & Becker (2003) revealed that the selection

of a certain rice cultivar (low and high GI rice varieties), as well as the adaptation of processing/cooking might offer the possibility of substantially reducing the glycaemic response of ingested rice (Frei *et al.*, 2003). Another *in vivo* study reported a reduction in GI of two Pakistani basmati rice varieties when microwave oven was used compared to an electric cooker (Gunathilaka & Ekanayake, 2015). Our study observed an increase in SDS which could possibly indicate a reduction in GI when microwave cooking was applied. Future investigations could look deeper into the texture qualities of cooked rice, degree of gelatinisation and amylose-amylopectin structure of these rice varieties. A comparison of the changes occurring before and after cooking, with these two methods, would be an important area to explore.

CONCLUSION

The present study reports that starch digestibility can be significantly altered when rice is cooked using a microwave oven compared to an electric cooker. Microwave cooking could be recommended as a simple tool to lower the glycaemic response of high GI rice, such as white rice. In many countries in Asia, where large quantities of rice are consumed, microwave cooking is a simple and practical way to reduce the glycaemic response of rice. Given the widespread interest in consuming low GI foods in Asia, the potential intervention of using simple culinary methods to reduce glycaemic response maybe through (a) choosing appropriate cooking methods such as microwaving (b) selecting low GI rice varieties, (c) selecting black, brown or purple rice over white rice. However, further research is necessary to translate *in vitro* observations into *in vivo* human trials to validate these findings.

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Authors' contributions

BK, conducted data analysis and interpretation, drafted and reviewed manuscript; JL, conducted data analysis and interpretation, drafted and reviewed manuscript; CC, carried out *in-vitro* work and analysed the data; CJH, conducted data analysis and interpretation, drafted and reviewed manuscript.

Conflict of interest

All authors declare no conflict of interest.

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Vitamin D status is associated with high BMI, working status and gravidity among pregnant Malaysian women

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ABSTRACT

Introduction: Vitamin D deficiency (VDD) is associated with adverse health outcomes in pregnancy and newborns. This study aims to determine the Vitamin D status among pregnant Malaysian women and its associations with specific maternal & pregnancy characteristics. **Methods:** This study utilised cross-sectional data from a prospective cohort study of pregnant women in Seremban district in which 259 pregnant women had available vitamin D data. Blood samples were taken <14th week of gestation. Serum 25-hydroxy Vitamin D [25(OH)D] levels were analysed using chemiluminescent microparticle immunoassay (CMIA) technology on the ARCHITECT iSystem and categorised using the Institute of Medicine (IOM) 2011 cut-offs. A set of pre-tested interviewer-administered questionnaire was used to obtain information on socio-demographics, obstetrics, and anthropometry. **Results:** Mean serum 25(OH)D was 32.83±11.37nmol/L. The prevalence of severe and mild VDD was 23.2% (*n*=60) and 68.3% (*n*=177), respectively. About 8.5% (*n*=22) of pregnant women were vitamin D insufficient and none had sufficient serum 25(OH)D (>75nmol/L). Early pregnancy body mass index (AOR=2.95, 95% CI=1.03-8.47), working status (AOR=3.17, 95% CI=1.06-9.50) and gravidity (AOR=0.68, 95% CI=0.48-0.98) were significantly associated with VDD. **Conclusion:** The present study showed a high prevalence of VDD among pregnant women in Malaysia, especially among those who were overweight or obese, working in indoor environment and primigravida.

Keywords: Vitamin D deficiency (VDD), serum 25(OH)D, BMI, pregnant women, Malaysia

INTRODUCTION

Vitamin D deficiency (VDD) (serum 25-hydroxy Vitamin D [25(OH)D] <50nmol/L) has become a public health concern globally, cutting across all age groups. In Europe, about 30–65% of adults were reported having VDD, while in Asia, the prevalence among

adults was about 50–70% (Palacios & Gonzalez, 2014). Among healthy women in the reproductive age of between 15–45 years old, the prevalence of VDD was 60–73% in Asia (Green *et al.*, 2008; Junaid *et al.*, 2015), while in the United States it was 41% (Ginde *et al.*, 2010). To date, consensus regarding

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optimal levels of serum 25(OH)D has not been established, although most experts define VDD as serum 25(OH)D level of <20ng/ml (50nmol/L) and vitamin D insufficiency as 21-29ng/ml (52-72nmol/L) (IOM, 2011).

The traditional function of vitamin D is associated with musculoskeletal health and bone mineralisation. However, there are increasing evidences supporting the association between VDD with cardiovascular diseases, cancer, autoimmune diseases and diabetes (Kulie *et al.*, 2009). The beneficial effects of vitamin D in reducing the risk of cardiovascular diseases appear to be via its role in the regulation of blood pressure, weakening the actions of the renin-angiotensin-aldosterone system and suppressing cellular inflammation of cardiac cells (Wimalawansa, 2016). Vitamin D also acts as an anti-inflammatory agent and assists in maintaining the equilibrium between pro- and anti-inflammatory situations in autoimmune diseases (Dankers *et al.*, 2017). In addition, vitamin D and its metabolites reduce the incidence of cancer by inhibiting cell proliferation, stimulating apoptosis, suppressing inflammation, as well as inhibiting tumour angiogenesis, invasion and metastasis (Krishnan *et al.*, 2012). Meanwhile, the role of vitamin D in glucose tolerance is demonstrated by its ability to affect insulin secretion from β -cells in the pancreas and insulin sensitivity (Martin & Campbell, 2011).

VDD is also common during pregnancy with a prevalence in the range of 21-91% across developed and developing countries (Ravinder *et al.*, 2015; Richard, Rohrmann & Löttscher, 2017). VDD in pregnancy has been associated with adverse pregnancy outcomes, including gestational diabetes mellitus (GDM), preeclampsia, bacterial vaginosis, a shorter gestation

period, increase in caesarean section births and post-partum depression (Charatcharoenwitthaya *et al.*, 2013). Adverse associations of VDD on newborns include higher incidences of small-for-gestational age (SGA), reduced infant bone mineral density and rickets (Mulligan *et al.*, 2010). Infants born to women with VDD are also at risk for developing respiratory infections, asthma, type 1 diabetes and schizophrenia later in life (Mulligan *et al.*, 2010; Hart *et al.*, 2015). Among the established risk factors for VDD in pregnancy are high latitude, winter season and high body mass index (BMI) (Vandevijvere *et al.*, 2012). Meanwhile, physical activity level, ethnicity, educational level and exposure to sunlight showed inconsistent associations with vitamin D status (Wagner *et al.*, 2016; Bukhary *et al.*, 2016). Dietary intake and exposure to sunlight are the two main sources of Vitamin D. However, due to limited food sources of Vitamin D, either naturally present in foods or added to foods, exposure to sunlight is therefore regarded as the main source of Vitamin D in most countries (Holick, 2017).

In Malaysia, despite the abundance of sunlight, nearly 70% of adults have been reported to be vitamin D deficient (Shafinaz & Moy, 2016). However, data on VDD incidence among pregnant women in the country are limited. Bukhary *et al.* (2016) reported that about 90.4% of pregnant mothers in Selangor had VDD and that the median of Vitamin D level was 27.11nmol/L. Jan Mohamed *et al.* (2014) reported that about two-thirds (59.8%) of pregnant mothers in their second trimester of pregnancy in Kelantan showed VDD. Thus, this study aimed to further investigate the prevalence of VDD among Malaysian pregnant women, as well as factors associated with vitamin D status.

MATERIALS AND METHODS

This study utilised cross-sectional data from The Seremban Cohort Study (SECOST), which was a prospective cohort study where pregnant women and their infants were followed-up until two years postnatal. Women in their first trimester of pregnancy (<14th week of gestation) were recruited from three Maternal and Child Health (MCH) clinics in the district of Seremban, Negeri Sembilan. The details of this study have been previously reported (Yong *et al.*, 2018). A total of 259 pregnant women whose vitamin D data were collected were included in this study. The sample size was determined by exclusion of individuals diagnosed with diabetes in pregnancy (DIP) or GDM by the MCH clinics ($n=57$), miscarriage ($n=28$), and drop-out or loss of contact during study period ($n=44$), participants who withdrew ($n=38$), and those without available vitamin D data ($n=311$) (Figure 1).

A set of pre-tested interviewer-administered questionnaires was used for data collection. Demographic and socioeconomic information obtained

were age, ethnicity, marital status, educational level, monthly household income, household size, as well as gravidity. Respondents' weight and height were measured at study enrolment using standard instruments (SECA digital weighing scale, and SECA body meter). Early pregnancy body weight was obtained from the medical records at the health clinics. Early pregnancy height and body weight were used to calculate early pregnancy BMI, as weight (kg) divided by the square of height (m²). Fasting venous blood samples (5ml) were drawn into a plain tube during the booking period (<14th week of gestation) by trained nurses to quantify serum 25(OH)D. Maternal serum 25(OH)D levels were analysed using chemiluminescent microparticle immunoassay (CMIA) technology on the ARCHITECT iSystem and categorised as severe VDD (<25nmol/L), mild VDD (25–<50nmol/L), vitamin D insufficiency (50–<75nmol/L) and vitamin D sufficiency (≥ 75 nmol/L) (IOM, 2011).

The study protocol was approved by the Medical Research Ethics Committee

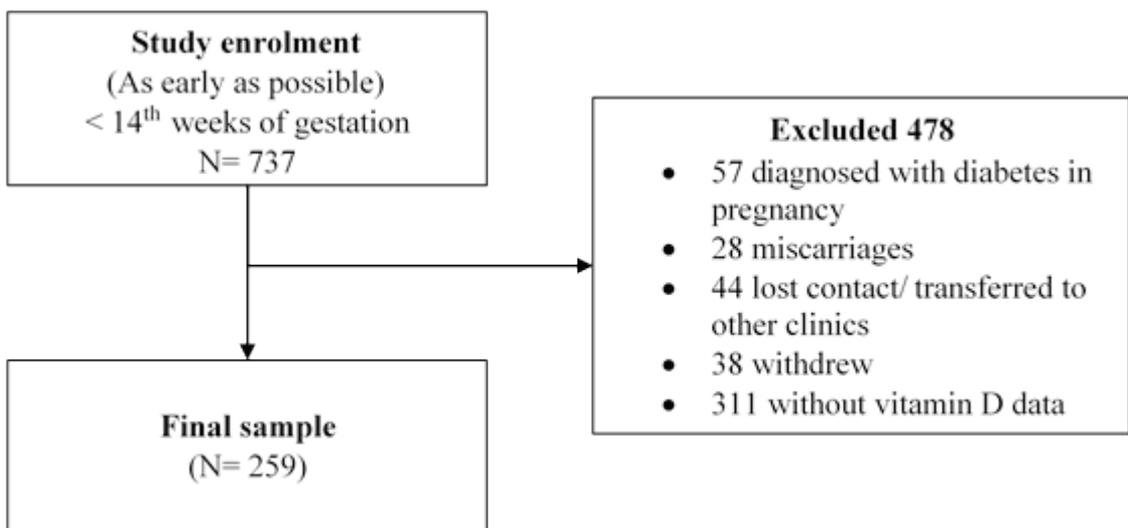


Figure 1. Sampling procedure

(MREC), Universiti Putra Malaysia (UPM/FPSK/100-9/2-MJKEtika) and the Medical Research Ethics Committee (MREC), Ministry of Health Malaysia (KKM/NIHSEC/08/0804/P12-613). Permission to conduct this study was also obtained from the Head of the Seremban District Health Office. All women gave informed consent prior to study enrolment.

Statistical analysis

Statistical analysis was performed using the SPSS statistical software package version 22 (SPSS Inc., Chicago, IL, USA). Exploratory Data Analysis (EDA) was carried out to determine the normality and homogeneity of the data. All variables were described using descriptive statistics. Chi-square test of independence or the Fisher's exact test and Analysis of Variance (ANOVA) test were used to assess the associations between the characteristics of women with serum Vitamin D levels, for categorical and continuous variables, respectively.

Multiple logistic regression was performed to determine the associations

between the independent variables and VDD, and adjusted for covariates. Covariates included in the multivariable model were age, ethnicity and years of education. Adjusted odds ratio (OR) with 95% confidence interval (CI) were presented. Statistical significance was set at $p < 0.05$.

RESULTS

The distributions of serum 25(OH)D are shown in Figure 2. Mean serum 25(OH)D was 32.83 ± 11.37 nmol/L. The prevalence of severe and mild serum 25(OH)D deficiency was 23.2% ($n=60$) and 68.3% ($n=177$), respectively. About 8.5% of the pregnant women ($n=22$) were found to have serum 25(OH)D insufficiency. None of the women showed sufficient serum 25(OH)D (>75 nmol/L) levels according to the Institute of Medicine (IOM) criteria.

Table 1 describes the socio-demographic and obstetrical characteristics of pregnant women in the study. The mean age of women in the study cohort was 30.50 ± 4.42 years, majority being Malay (93.4%) and employed (73.0%). The mean years of

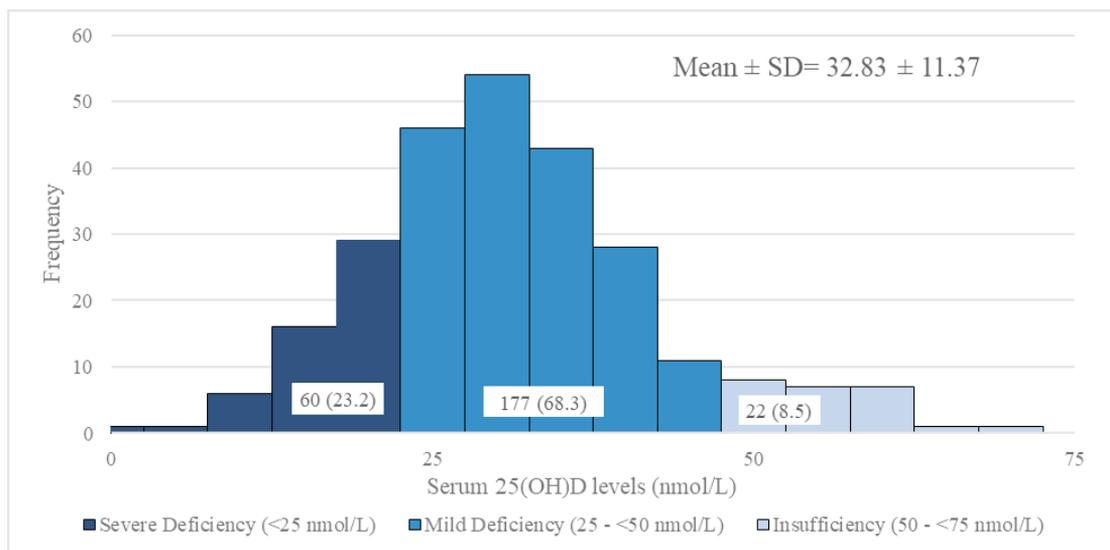


Figure 2. Distribution of serum 25(OH)D levels in pregnant women ($N=259$)

Table 1. Characteristics of pregnant women by serum 25(OH)D levels (N=259)

	Serum 25(OH)D levels (nmol/L)				F/ χ^2	p-value
	Total (N=259)	Severe deficiency (<25) (n= 60)	Mild deficiency (25-<50) (n=177)	Insufficiency (50-<75) (n=22)		
		Mean \pm SD / n (%)				
Socio-demographic factors						
Age (years)	30.50 \pm 4.42	29.53 \pm 4.14	30.82 \pm 4.51	30.63 \pm 4.20	1.92	0.15
≤30	143 (55.2)	35 (58.3)	96 (54.2)	12 (54.5)	3.19 ^s	0.49
31-40	110 (42.5)	25 (41.7)	75 (42.4)	10 (45.5)		
>40	6 (2.3)	0 (0.0)	6 (3.4)	0 (0.0)		
Ethnicity						
Malay	242 (93.4)	53 (88.3)	168 (94.9)	21 (95.5)	3.07 ^s	0.20
Non Malay	17 (6.6)	7 (11.7)	9 (5.1)	1 (4.5)		
Employment						
Unemployed	70 (27.0)	10 (16.7)	51 (28.8)	9 (40.9)	5.70	0.05
Working	189 (73.0)	50 (83.3)	126 (71.2)	13 (59.1)		
Education (years)	13.14 \pm 2.47	13.83 \pm 2.55 ^a	12.96 \pm 2.38 ^a	12.64 \pm 2.72	2.91	0.04*
Secondary and lower	115 (4.4)	20 (33.3)	83 (46.9)	12 (54.6)	5.72	0.22
STPM/ Matric/ Diploma/ Certificate	92 (35.5)	24 (40.0)	63 (35.6)	5 (22.7)		
Tertiary and above	52 (20.1)	16 (26.7)	31 (17.5)	5 (22.7)		
Monthly household income (MYR) [†]	4079.75 \pm 2136.70	4522.57 \pm 1880.37	3969.50 \pm 2197.83	3759.09 \pm 2214.17	1.78	0.17
Low (<3860)	141 (54.4)	26 (43.3)	101 (57.1)	14 (63.6)	5.10	0.28
Middle (3860-8319)	110 (42.5)	31 (51.7)	72 (40.7)	7 (31.8)		
High (≥8320)	8 (3.1)	3 (5.0)	4 (2.2)	1 (4.4)		
Obstetrical factors						
Gravidity						
1	2.49 \pm 1.38	2.17 \pm 1.21 ^b	2.55 \pm 1.41	2.95 \pm 1.50 ^b	3.09	0.04*
2	69 (26.6)	21 (35.0)	45 (25.4)	3 (13.6)	6.44	0.17
≥3	86 (33.2)	22 (36.7)	56 (31.6)	8 (36.4)		
Height (m)	104 (40.2)	17 (28.3)	76 (42.9)	11 (50.0)	1.27	0.28
<1.55	1.57 \pm 0.06	1.57 \pm 0.06	1.56 \pm 0.06	1.58 \pm 0.05	4.71	0.32
1.55-1.59	88 (34.0)	20 (33.4)	62 (35.0)	6 (27.3)		
≥1.60	93 (35.9)	23 (38.3)	65 (36.7)	5 (22.7)		
Weight (kg)	78 (30.1)	17 (28.3)	50 (28.3)	11 (50.0)	0.59	0.56
BMI (kg/m ²) [‡]	60.44 \pm 12.69	59.94 \pm 10.35	60.91 \pm 13.51	57.97 \pm 11.68	1.41	0.25
Underweight (<18.5)	24.57 \pm 4.89	24.27 \pm 4.01	24.86 \pm 5.19	23.10 \pm 4.45	10.82 ^s	0.07
Normal (18.5-24.9)	17 (6.6)	1 (1.7)	15 (8.5)	1 (4.5)		
Overweight (25.0-29.9)	133 (51.4)	34 (56.6)	83 (46.9)	16 (72.7)		
Obese (≥30.0)	69 (26.6)	19 (31.7)	48 (27.1)	2 (9.1)		
	40 (15.4)	6 (10.0)	31 (17.5)	3 (13.6)		

[†]Economic Planning Unit, Prime Minister's Department, 2014. 1 USD was equivalent to Malaysian Ringgit (MYR) 4.22 at the time of study

[‡]BMI at 10-14th week of gestation

[§]Fisher's exact test

^{a,b} Means that are in the same row with similar superscript letters are significantly different (p<0.05)

*p<0.05

Table 2. Unadjusted OR and 95% CI of factors associated with serum 25(OH)D levels in pregnant women (N=259)

	Serum 25(OH)D levels (nmol/L)			
	Severe deficiency (<25) (n= 60)		Mild deficiency (25-<50) (n=177)	
	Unadjusted OR [95% CI]	p-value	Unadjusted OR [95% CI]	p-value
Socio-demographic factors				
Age (years)	0.94 [0.84 – 1.05]	0.29	1.01 [0.91 – 1.12]	0.85
Ethnicity				
Malay	1.00		1.00	
Non Malay	2.77 [0.32 – 23.94]	0.35	1.13 [0.14 – 9.33]	0.91
Employment				
Unemployed	1.00		1.00	
Working	3.46 [1.17 – 10.27]	0.03*	1.71 [0.69 – 4.25]	0.25
Education (years)				
Secondary and lower	1.00		1.00	
STPM/ Matric/ Diploma/ Certificate	2.88 [0.87 – 9.56]	0.08	1.82 [0.61 – 5.44]	0.28
Tertiary and above	1.92 [0.56 – 6.59]	0.30	0.90 [0.29 – 2.75]	0.85
Monthly household income (MYR)†				
Low (<3860)	1.00		1.00	
Middle (3860 – 8319)	2.39 [0.84 – 6.79]	0.10	1.43 [0.55 – 3.71]	0.47
High (≥8320)	1.62 [0.15 – 17.02]	0.69	0.55 [0.06 – 5.32]	0.61
Obstetrical factors				
Gravidity				
1	1.00		1.00	
2	0.39 [0.09 – 1.68]	0.21	0.47 [0.12 – 1.86]	0.28
≥3	0.22 [0.05 – 0.92]	0.04*	0.46 [0.12 – 1.74]	0.25
Height (m)				
<1.55	1.00		1.00	
1.55 – 1.59	0.83 [0.37 – 5.22]	0.64	0.94 [0.36 – 4.33]	0.72
≥1.60	0.46 [0.14 – 1.52]	0.20	0.44 [0.15 – 1.27]	0.13
BMI (kg/m ²)‡				
Non-overweight/obese (<25.0)	1.00		1.00	
Overweight/obese (≥25.0)	2.43 [0.79 – 7.45]	0.12	2.74 [0.97 – 7.76]	0.04*

Reference category is vitamin D insufficiency, defined as serum 25(OH)D 50 – <75 nmol/L (n=22)

†Economic Planning Unit, Prime Minister's Department, 2014. 1 USD was equivalent to Malaysian Ringgit (MYR) 4.22 at the time of study

‡BMI at 10–14th week of gestation

*p<0.05.

education was 13.14±2.47 years, and the mean monthly household income was RM4,079.57±2,136.70. Mean gravidity was 2.49±1.38. Mean height and weight of the pregnant women were 1.57±0.06m and 60.44±12.69kg, respectively. The calculated early pregnancy mean BMI amounted to 24.57±4.89kg/m², indicating that approximately half of the women (51.4%) had a healthy BMI.

Among the variables, only years of education and gravidity were significantly associated with serum 25(OH)D levels.

Table 2 and Table 3 describe the unadjusted and adjusted OR and 95% CI for factors associated with serum 25(OH)D levels in pregnant women. In the unadjusted logistic model, early pregnancy BMI (OR=2.74, 95% CI=0.97-7.76), employment status (OR=3.46, 95%

Table 3. Multivariable analysis of factors associated with serum 25(OH)D levels in pregnant women (N=259)

	Serum 25(OH)D levels (nmol/L)											
	Model 1 [†]				Model 2 [‡]				Model 3 [§]			
	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)	Severe deficiency (<25) (n=60)	Mild deficiency (25-<50) (n=177)
BMI (kg/m ²)												
Non-overweight/obese	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Overweight/obese	2.62 [0.84 -8.16]	0.09 [1.03 -8.47]	0.04* [1.02 -10.36]	0.04* [1.02 -8.97]	0.04* [1.02 -8.97]	0.04* [1.02 -8.97]	0.04* [1.11 -11.79]	0.03* [1.03 -8.99]	0.04* [1.03 -8.99]	0.03* [1.11 -11.79]	0.03* [1.03 -8.99]	0.04* [1.03 -8.99]
Employment												
Unemployed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Working	3.17 [1.06 -9.50]	0.04* [1.57 -3.94]	0.34 [1.08 -9.88]	0.04* [1.56 -3.94]	0.34 [1.08 -9.88]	0.34 [1.56 -3.94]	0.06 [0.95 -8.89]	0.06 [0.95 -8.89]	0.06 [0.95 -8.89]	0.06 [0.95 -8.89]	0.06 [0.95 -8.89]	0.38 [1.51 -3.85]
Gravidity												
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.36 [0.08 -1.56]	0.17 [0.45 -1.80]	0.26 [0.36 -1.58]	0.18 [0.44 -1.75]	0.18 [0.44 -1.75]	0.24 [0.35 -1.53]	0.16 [0.08 -1.73]	0.16 [0.08 -1.73]	0.16 [0.08 -1.73]	0.16 [0.08 -1.73]	0.16 [0.08 -1.73]	0.23 [0.43 -1.73]
≥3	0.22 [0.05 -0.90]	0.04* [0.46 -1.72]	0.25 [0.25 -1.19]	0.08 [0.38 -1.64]	0.08 [0.38 -1.64]	0.19 [0.32 -1.58]	0.16 [0.06 -1.58]	0.16 [0.06 -1.58]	0.16 [0.06 -1.58]	0.16 [0.06 -1.58]	0.16 [0.06 -1.58]	0.23 [0.41 -1.77]

The reference category is vitamin D insufficiency, defined as serum 25(OH)D 50 - <75 nmol/L (n=22).

[†]Adjusted for gestational week when blood sampling was performed

[‡]Adjusted for covariate in model 1 + age, and ethnicity;

[§]Adjusted for covariates in model 2 + years of education

*p<0.05

CI=1.17-10.27) and gravidity ($OR=0.22$, 95% CI=0.05-0.92) were significantly associated with vitamin D status (Table 2). Overweight/obese pregnant women were three times at higher risks for severe ($AOR=3.61$, 95% CI=1.11-11.79) and mild ($AOR=3.06$, 95% CI=1.03-8.99) VDD compared to non-overweight/obese pregnant women. The significant association between early pregnancy BMI and VDD persisted after adjusting for covariates. Working pregnant women were 3.27 times more likely to have severe serum 25(OH)D deficiency compared to unemployed pregnant women ($AOR=3.27$, 95% CI=1.08-9.88). However, this association was no longer significant after further adjustment for years of education. Pregnant women with gravidity ≥ 3 were less likely to have severe VDD compared to primigravid women ($AOR=0.22$, 95% CI=0.05-0.90). Yet again, significance was lost when the models were adjusted for age, ethnicity and years of education.

DISCUSSION

The present study showed that about 91.5% of pregnant women in their early pregnancy had severe to mild VDD (serum 25(OH)D $< 50\text{nmol/L}$). These results appear to be quite similar to the results in a local study conducted in Selangor which reported that about 90.4% of pregnant women in their first trimester of pregnancy had VDD (Bukhary *et al.*, 2016). Although lower prevalence of VDD has been reported among women in the first trimester of pregnancy in Thailand (26.7%) and Vietnam (19.0%) (Charatcharoenwitthaya *et al.*, 2013; Hien *et al.*, 2011), direct comparison between studies should be done with caution, as the method to analyze serum vitamin D (Charatcharoenwitthaya *et al.*, 2013) and cut-offs to define VDD (Hien *et al.* 2011) were different. Lack of exposure to sunlight cannot explain

these observed differences in VDD prevalence as Malaysia, Thailand and Vietnam are all tropical countries with abundant sunlight throughout the year. A plausible explanation could be the differences in dressing attire of women. Since approximately 93.4% of pregnant women in the present study were Muslims, thus they are covered in dressing attires that exposed less skin surface to sunlight. Previous studies have shown that covered dressing style due to religious or cultural factors, is indeed an important determinant of VDD in Muslim populations (Parlak *et al.*, 2012).

Low mean serum 25(OH)D and high prevalence of VDD were also reported for non-pregnant women in Malaysia. Green *et al.* (2008) found that women of child-bearing age living in Kuala Lumpur had a low mean serum 25(OH)D of 49.0nmol/L and the percentage of women with severe ($< 17.5\text{nmol/L}$) and mild ($< 50\text{nmol/L}$) VDD were 0.3% and 60.0%, respectively. Studies among workers in a public university (Moy & Bulgiba, 2011) and secondary school teachers (Shafinaz & Moy, 2016) reported an overall VDD prevalence of 67.4 and 67.9%, respectively. These two studies also showed that women ($36.2\text{--}43.5\text{nmol/L}$) had significantly lower mean serum 25(OH)D than men ($56.2\text{--}63.1\text{nmol/L}$).

In the present study, early pregnancy BMI was significantly associated with vitamin D status. Previous studies also indicated that overweight or obese pregnant women were more likely to have VDD compared to normal weight pregnant women (Vandevijvere *et al.*, 2012; Karlsson *et al.*, 2015). Variability in vitamin D status by adiposity can be explained by the role of subcutaneous fat, which is the storage site for cutaneous synthesised Vitamin D₃. In an obese person, vitamin D₃ will be actively retained in the subcutaneous

fat, which then reduces the conversion of vitamin D₃ to 25(OH)D in the liver, causing low circulating levels of serum 25(OH)D (Wortsman *et al.*, 2000). Another possible explanation for the association of Vitamin D and adiposity is through volumetric dilution mechanism. Vitamin D is fat soluble and stored mainly in fat, muscles, and liver, with smaller amounts in other tissues. As all these tissues and organs expand in an obese person, there will be increased amount of vitamin D distributed into these tissues and organs, consequently decreasing the amount of vitamin D in the circulation (Walsh, Bowles & Evans, 2017).

The study found that employed pregnant women were more likely to have severe VDD compared to unemployed pregnant women. This could be due to the nature of jobs that require women to work in a closed environment with limited sun exposure. In China, pregnant women who were working indoors with limited exposure to sunlight were reported to have an average level of 36.7nmol/L of serum 25(OH)D (Xiang *et al.*, 2013). Studies have reported that limited exposure to sunlight affects Vitamin D level in the body as the synthesis of vitamin D in human body depends predominantly on skin exposure to Ultraviolet (UV) B light from direct sunlight (Flood-Nichols *et al.*, 2015). Furthermore, usage of sunblock lotions could also limit the ability of the skin to synthesise Vitamin D (Wagner *et al.*, 2016). Interestingly, the present study showed that gravidity was significantly associated with VDD where pregnant women with gravidity ≥ 3 were less likely to have severe VDD compared to primigravid women. Further analyses were performed to assess the associations between gravidity with employment status and BMI. While BMI did not show any significant association with gravidity, there were

significantly more primigravid women who were employed (76.8%) compared to women with gravidity ≥ 3 (23.2%). This observation supports our finding that employed women were at higher risks of VDD due to working environment that limits exposure to sunlight.

The inability to evaluate the underlying factors contributing to VDD such as usage of sunscreen lotion, skin pigmentation, socio-economic status and lifestyle behaviours was a limitation of this study. Applying early pregnancy BMI as a contributing factor instead of pre-pregnancy BMI where the latter has been widely used to ascertain the association between maternal VDD and BMI was also noted as a limitation in this study. Nevertheless, the use of early pregnancy BMI could help to avoid recall bias by pregnant women in reporting their pre-pregnancy BMI. Vitamin D intake (from foods and dietary supplements) and sun exposure are major determinants of vitamin D status. Sun exposure was not measured in the study although the working status of women in the study could be a proxy to the amount of sun exposure. For vitamin D intake, an analysis of sub-sample ($N=170$) showed that mean vitamin D intake from foods and supplements were $4.65 \pm 0.34 \mu\text{g}/\text{day}$ and $2.58 \pm 0.42 \mu\text{g}/\text{day}$ (data not shown), respectively. However, no significant association between total vitamin D intake and serum 25(OH)D was observed in this sub-sample of women. Despite these limitations, this study adds to the existing limited findings on serum 25(OH)D levels in the first trimester of pregnancy.

CONCLUSION

VDD is prevalent in this selected sample of pregnant women and among those who were overweight or obese, working and had lower gravidity. It is important to promote awareness on the importance of

Vitamin D during pregnancy as vitamin D is essential not only for healthy bones, but also plays a role in disease prevention and health outcomes for both the mother and her offspring. Educating pregnant women on maintaining a healthy BMI and gaining adequate weight throughout pregnancy should be conducted to minimise the risk of VDD among them. Health care system should consider providing VDD screening to pregnant women during early pregnancy for consideration of advice or intervention. Pregnant women should be encouraged to consume vitamin D-rich foods, but even more importantly, to be exposed to adequate sunlight regularly to increase endogenously synthesised Vitamin D.

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Authors' contributions

LP, analysed the data and constructed the draft manuscript, contributed to the review and approval of the final manuscript; YHY, responsible for the concept and project development, supervised the project's progress; contributed to the review and approval of the final manuscript; ZMS, responsible for the concept and project development, supervised the project's progress, contributed to the review and approval of the final manuscript; LSP, responsible for the concept and project development, supervised the project's progress, contributed to the review and approval of the final manuscript; JB, responsible for the concept and project development, contributed to the review and approval of the final manuscript; YYST, responsible for the concept and project development, contributed to the review and approval of the final manuscript; EMVDB, responsible for the concept and project development, contributed to the review and approval of the final manuscript.

Conflict of interest

The authors declare that they have no conflict of interests. The funders had no roles in data collection, data analysis or data interpretation.

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