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Development and validation of a nutrient profiling model for Malaysian older population

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ABSTRACT

Introduction: Nutrient profiling is the science of ranking food based on the nutrient content that enables an individual to make healthier food choice without exceeding the daily energy recommendation. This study was aimed at developing and validating a nutrient profiling model for Malaysian older population. **Methods**: A total of six nutrient profiling models comprising different combinations of nutrients were developed. Each model was tested by scoring 94 food items in terms of 100 kcal and 100 g, and the Recommended Nutrient Intakes for Malaysian (2017) as the reference value. The scores in each model were correlated with energy density per 100 g of food. The best model to correctly rank food according to nutrient density was chosen for validation. Validation was done by comparing the healthiness classification of 174 food items as determined by Towards Useful Aging Food Nutrient Density Index (TUA FNDI) nutrient profiling model and the Malaysian Dietary Guidelines. **Results:** Models with sodium and total fat were better correlated with energy density. All six models were inversely correlated with energy density. TUA FNDI 9-2 model was chosen as the best model for validation. Overall, there was substantial agreement between TUA FNDI 9-2 model and the food-based dietary guidelines (κ=0.644, p=0.001). **Conclusion:** The inverse correlation between nutrient profiling models to energy density shows that foods with higher nutrient density contain lower energy. The validated TUA FNDI 9-2 model is recommended for older adults to make healthier food choices.

Keywords: Nutrient profiling, nutrient density, nutrient-dense food

INTRODUCTION

Nutrient profiling is the science of classifying or ranking foods according to their nutritional composition for application in disease prevention and health promotion (WHO, 2011). The idea of nutrient profiling evolved from the concept of nutrient density of food, which studies the nutrient content in a food item compared to the amount of energy that the food provides (Drewnowski, 2009). A nutrient-dense food contains a higher amount of nutrients than calories (McGuire, 2011). Although there is a wide range of nutrients in a food item, there are no specific criteria of the amounts and types of nutrients that should be included in order to classify a food as nutrient-dense (Drewnowski & Fulgoni, 2008). Hence, nutrient profiling provides a solution with a clearer basis and systematic approach to categorise food

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based on the amount of nutrient content. It enables food to be evaluated based on a specific algorithm or scoring system that contains several nutrients of interest that are related to a particular population (Garsetti *et al.*, 2007). For example, the Nutrient Rich Food (NRF) model that was developed for American population (Fulgoni, Keast & Drewnowski, 2009), and the UK Ofcom Nutrient Profiling Model that was developed by the United Kingdom Food Standards Agency (FSA) to monitor the advertisement of food products for children (Scarborough *et al.*, 2007). There are several applications of nutrient profiling model including nutritional quality assessment of a food, consumer education (Garsetti *et al.*, 2007), determination of eligibility of a food to carry the health claim for display as front-of-pack labelling, and reformulation of food product (Sacks *et al.*, 2011).

Nutrient profiling model needs to be specific and suitable for the target population. There is currently no nutrient profiling model that has been developed specifically for Malaysian older population. The interest to develop a nutrient profiling model for this population arises from the concern of poor nutritional status among older Malaysians (Nik Mohd Fakhruddin *et al.*, 2016). Physiological changes such as alteration of taste bud, changes in absorption and digestion process, presence of disease, polypharmacy and various psychological factors might leave a direct impact to elderly food intake, and thus resulted in reduction of energy intake (Malafarina *et al.*, 2013). Moreover, changes in body composition that usually comes with ageing lead to decrease in body's metabolism and consequently the decrease in energy requirement (St-Onge & Gallagher, 2010). However, despite all these changes, the nutrient requirement for elderly individuals either remained the same or increased (ter Borg *et al.*, 2015). Decreases in energy requirement and energy intake made obtaining sufficient amounts of nutrient a rather difficult process (Bernstein & Munoz, 2012).

Lack of nutrition knowledge was an indirect contributing factor of the failure of older Malaysians to adhere to the nutrient recommendations (Karim *et al.* 2008). The elderly should be provided with information on how to make healthier food choices (Bernstein & Munoz, 2012). Previous research had indicated that people with nutrient-dense diet (as assessed by nutrient profiling method) had a decreased risk of cardiovascular disease, diabetes and all-cause mortality (Chiuve *et al.*, 2012). This study aims to develop and validate a nutrient profiling model that identifies the nutrient density of food items, which will enable the elderly to make an informed food choice.

MATERIALS AND METHODS

Characteristics of the nutrient profiling model

The nutrient profiling model for Malaysian older population named Towards Useful Aging Food Nutrient Density Index (TUA FNDI), consisted of a combination of positive and negative nutrients. "Positive nutrients" are nutrients that should be taken in adequate amounts for health, while "negative nutrients" refers to nutrients that should be taken in limited amounts due to negative effects on health when taken excessively (Garsetti *et al.*, 2007).

This model was calculated using the threshold system that used certain reference values as a cut-off point to indicate the adequacy of nutrient intake (Garsetti *et al.*, 2007). The reference values used in this study were taken from the Recommended Nutrient Intakes for Malaysian Population (RNI) (NCCFN, 2017), for males aged ≥60 years with moderately active physical activity level 1.6. The RNI recommendations for most nutrients are similar for both sexes, although for males, the recommended values for thiamine, riboflavin, niacin, iron and protein are slightly higher. Percentage RNI values for all nutrients were capped at 100% "as an act of fairness to avoid giving extra reward to any food item that contained extremely high amount of a positive nutrient and to avoid unnecessary penalisation of food items with very high amount of negative nutrient" (Drewnowski, 2005). Next, the algorithm used was the difference between the average sum of positive nutrients and the average sum of negative nutrients. Since this model used average values, it tends to give extra weight to the negative nutrients. This model was designed to give more weight to the negative nutrients as a precautionary step when addressing the nutrient needs of the older adult population with a high prevalence of chronic diseases. The development of this model used the similar approach as Drewnowski, Maillot & Darmon (2009), including the algorithm consisting of both negative and positive nutrients and the nutrient threshold level. However, the TUA FNDI model used different nutrients of interest appropriate for the needs of Malaysian elderly.

Selected nutrients

The choice of nutrients included in this study were based on previous studies on nutrient intake among communities with Malaysian older population (Shahar *et al.*, 2007; Nik Mohd Fakhruddin *et al.*, 2016), nutrient concerned stated in the RNI (NCCFN, 2017) and the availability of complete nutrients data in the Malaysian Food Composition database (Tee *et al.*, 1997). The algorithm of TUA FNDI was formulated to reflect healthy food intake as recommended by Malaysian Dietary Guidelines 2010 (MDG) (NCCFN, 2010). A total of eleven nutrients were selected for this model, including nine positive nutrients namely, protein, calcium (Ca), iron (Fe), potassium (K), vitamin A (Vit A), vitamin C (Vit C), thiamine, riboflavin and niacin, and two negative nutrients namely, total fat and sodium (Na). This model excluded total sugar due to a lack of complete nutrient data in the Malaysian Food Composition database (Tee *et al.*, 1997). Protein, Ca, Vit A and Vit C were added to indicate intake from "fish, meat, poultry and beans", "milk and milk products", and "fruits and vegetable" respectively. Nutrients that were added due to its low intake among the elderly were niacin (Nik Mohd Fakhruddin *et al.*, 2016), thiamine, riboflavin, Fe, and Ca (Shahar *et al.*, 2007). Potassium (K) was added to the model due to its health association with high blood pressure among the elderly (NCCFN, 2017).

Testing the TUA FNDI model

The TUA FNDI nutrient profiling models were tested to determine the best model that correctly categorised foods based on their nutrient density. A total of six models, each comprised a different nutrient combination was tested based on 100g and 100 kcal, making a total of twelve model variants (Table 1). The notation of TUA FNDI 7, 8 and 9 indicated that the models were made up of a combination of either 7, 8 or 9 positive nutrients. Meanwhile the notation of TUA FNDI *n*-1 or *n*-2 at the end indicated that the models consisted of one or two negative nutrients respectively. The test was conducted by correlating the score of a set of "test food" that was calculated using the TUA FNDI nutrient profiling model against energy density per 100 g of food.

The "test food" comprised a list of 94 food items that were extracted from the illustrated Malaysian Food Pyramid (NCCFN, 2010), and a selection of at least

Table 1. List of nutrient profile models tested and their building components

Nutrient profile model	*Reference value*	*Positive nutrients*	*Negative nutrients*	*Algorithm*
TUA FNDI 9-1	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, Niacin, K, Ca, Fe	Na	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{9}\right) - (\%\text{RNI Na})}{\%\text{RNI energy}}$
TUA FNDI 9-1	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, Niacin, K, Ca, Fe	Na	$\frac{\sum(\%\text{ RNI positive nutrients})}{9} - (\%\text{RNI Na})$
TUA FNDI 9-2	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, Niacin, K, Ca, Fe	Na, Total Fat	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{9}\right) - \sum\left(\frac{\%\text{RNI negative nutrients}}{2}\right)}{\%\text{RNI energy}}$
TUA FNDI 9-2	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, Niacin, K, Ca, Fe	Na, Total Fat	$\frac{\sum(\%\text{ RNI positive nutrients})}{9} - \frac{\sum(\%\text{RNI negative nutrients})}{2}$
TUA FNDI 8-1	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, K, Ca, Fe	Na	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{8}\right) - (\%\text{RNI Na})}{\%\text{RNI energy}}$
TUA FNDI 8-1	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, K, Ca, Fe	Na	$\frac{\sum(\%\text{ RNI positive nutrients})}{8} - (\%\text{RNI Na})$
TUA FNDI 8-2	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, K, Ca, Fe	Na, Total Fat	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{8}\right) - \sum\left(\frac{\%\text{RNI negative nutrients}}{2}\right)}{\%\text{RNI energy}}$
TUA FNDI 8-2	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, K, Ca, Fe	Na, Total Fat	$\frac{\sum(\%\text{ RNI positive nutrients})}{8} - \frac{\sum(\%\text{RNI negative nutrients})}{2}$
TUA FNDI 7-1	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, Ca, Fe	Na	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{7}\right) - (\%\text{RNI Na})}{\%\text{RNI energy}}$
TUA FNDI 7-1	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, Ca, Fe	Na	$\frac{\sum(\%\text{ RNI positive nutrients})}{7} - (\%\text{RNI Na})$
TUA FNDI 7-2	100 g	Protein, Vit A, Vit C, Thiamine, Riboflavin, Ca, Fe	Na, Total Fat	$\frac{\sum\left(\frac{\%\text{ RNI positive nutrients}}{7}\right) - \sum\left(\frac{\%\text{RNI negative nutrients}}{2}\right)}{\%\text{RNI energy}}$
TUA FNDI 7-2	100 kcal	Protein, Vit A, Vit C, Thiamine, Riboflavin, Ca, Fe	Na, Total Fat	$\frac{\sum(\%\text{ RNI positive nutrients})}{7} - \frac{\sum(\%\text{RNI negative nutrients})}{2}$

TUA FNDI= Towards Useful Aging Food Nutritional Density Index
RNI= Recommended Nutrient Intakes for Malaysians

five commonly consumed food reported in a study among Malaysian older population, (named "LRGS Towards Useful Aging (TUA) Neuroprotective Model for Healthy Aging" (LRGS TUA) (Nik Mohd Fakhruddin *et al.*, 2016).

The list of test foods comprised these food groups namely, "cereals, grains and tubers", "vegetables", "fruits", "fish, meat, poultry, eggs and beans", "milk and milk products", "fat, salt and sugar", "snacks and *kuih*". Beverages such as coffee, tea, soft drinks, and artificially-flavoured juices were excluded because of the lack of complete available information on nutrient content of these beverages. Traditional *kuih* (traditional Malaysian dessert) and snacks were included because the intake of *kuih* was high in the elderly population (Shahar, Earland & Rahman, 2000). The "test foods" were then ranked from the highest to the lowest nutrient density to determine which models provide the most consistent result (Drewnowski *et al.*, 2009).

Validation of nutrient profiling model

The validation of TUA FNDI was performed by comparing the healthiness of food items as determined by the food-based dietary guidelines and the nutrient profiling model. This is a form of determining content validity as a basic validation process (WHO, 2011; Wicks, 2012). For this purpose, another list that was made up of 174 food items was extracted from both written text and illustration form in MDG (NCCFN, 2010). This is to enable a direct comparison to be made between the healthiness of the food items that were classified by the MDG and TUA FNDI nutrient profiling model. More foods were included in the validation food list compared to the "test food" list to ensure a more robust validation process. Then, foods in the validation food list were placed into seven food categories according to the key messages of the MDG (NCCFN, 2010). Foods that were encouraged in the MDG were considered as "healthy". These included 'Key Message 4: Eat Adequate Amount of Rice, Other Cereal Products (Preferably Whole Grain) and Tubers', and 'Key Message 5: Eat Plenty of Fruits and Vegetables Everyday'. On the other hand, foods that were discouraged in the MDG such as 'Key Message 9: Choose and Prepare Food with Less Salt and Sauces', and 'Key Message 10: Consume Food and Beverages Low in Sugar' were considered as 'less healthy'. On the other hand, the determination of the healthiness of the food item based on the TUA FNDI nutrient profiling model was done by dividing the foods into quartile. Foods in the first two top tiles were considered as 'healthy' while foods in the bottom two tiles were considered as 'less healthy'. Foods that were considered 'healthy' were labelled as 'YES' while 'less healthy' foods were labelled as 'NO' (Arambepola, Scarborough & Rayner, 2008).

Statistical test

All the data were tested for the normal distribution using normality test such as Kolmogorov-Smirnov test, skewness and kurtosis. Data that were normally distributed was described in mean and standard deviation while data that were not normally distributed were described in median and interquartile range. Difference in sociodemographic characteristics, anthropometry characteristics and nutrient intake data of the participants were calculated using *t*-test for normally distributed data and Mann-Whitney U test for not normally distributed data. Correlation of food score generated by TUA FNDI model to energy density of food was done using Spearman's correlation. The comparison of the healthiness classification generated by MDG and TUA FNDI nutrient profiling model was done using kappa statistics to determine the level of agreement between the two methods. The *p*-value of ≤0.05 was considered as significant in this study.

This analysis made use of dietary data reported in the LRGS TUA study, which had included a total of 579 older subjects (Nik Mohd Fakhruddin *et al*., 2016). The subjects provided written informed consent at the beginning of the study. This study was approved by the Research Ethics Committee of Universiti Kebangsaan Malaysia (UKM 1.5.3.5/244/NN-060-2013).

RESULTS

Characteristics of the participants

The average age of the participants was 68.2±5.5 years, with the majority being male (55.1%), Malay (59.4%), married (74.6%) and retired (58.0%). The median body mass index (BMI) was in the normal category (24.6 kg/m^2), but the body fat percentage of the subjects was above the normal level (38.6%). Female subjects (25.5 kg/m^2, 44.4%) had significantly higher BMI and body fat percentage compared to male participants (24.1 kg/m^2, 33.8 %) (Table 2).

Calorie intake was lower than the recommendation, while protein and carbohydrate intake were above the recommendations. Intake of several nutrients such as vitamin A, vitamin C and iron were above the RNI recommendation, while that of thiamine, niacin, potassium and calcium were 70.0% below the recommended values (Table 3). Male subjects had significantly higher intake of energy, protein, carbohydrate, thiamine, riboflavin, sodium and iron as compared to female subjects.

Development of nutrient profiling model

The “vegetable” group had the highest median score, followed by “fruits” group and “fish, meat, poultry and bean” group. Meanwhile “fat, salt and sugar” group intake had the lowest median score across all the models tested. Table 4 shows median score for the food groups according to each nutrient profiling model tested.

Overall, all the models were inversely correlated with energy density (p=0.001) (Table 5). Nutrient profiling models with two negative nutrients had stronger correlation to energy density compared to models with only one negative nutrient included. Overall, the models with the strongest correlation to energy density were TUA FNDI 9-2 for 100 g variant (r=-0.715, p=0.001) and TUA FNDI 9-2 for 100 kcal variant (r=-0.712, p=0.001). Lowering the amount of nutrients included in the models had a very minor effect to the performance of these models.

The higher ranks were occupied by foods from the “vegetable” group while foods from “fat, salt and sugar” groups dominated the lower ranks. The 100 g formula appears to favour food with less water content in placing them at higher ranks. However, the 100 g formula showed lack of consistency when ranking foods that were usually taken in small amounts. For example, the 100 g formula put powdered skimmed milk 11 ranks lower than the 100 kcal formula but placed dried anchovies 8 ranks higher, compared to 100 kcal formula. On the other hand, the 100 kcal models were able to correctly rank the foods according to nutrient density regardless of weight and water content. As a result, TUA FNDI 9-2 model with 100 kcal calculation-base was chosen as the final model.

Validation of nutrient profiling model

The indicator foods were classified according to the healthiness of the food. A substantial level of agreement was obtained when 46.0% of the food was

Table 2. Participants' characteristics

Characteristics	*Male (n=319)*		*Female (n=260)*		*Total (n=579)*	
Age (years) (mean±*SD*)	68.8±5.4		67.4±5.5		68.2±5.5	
Age (years) (range)	60.0-85.0		60.0-85.0		60.0-85.0	
	n	%	*n*	%	*n*	%
Gender	319	55.1	260	44.9	579	100.0
Ethnicity						
Malay	199	62.4	145	55.8	344	59.4
Chinese	101	31.7	112	43.1	213	36.8
Indian	18	5.6	3	1.2	21	3.6
Others	1	0.3	0	0.0	1	0.2
Marital status*						
Single	11	3.5	1	0.4	12	2.1
Married	288	90.3	144	55.4	432	74.6
Divorced	1	0.3	5	1.9	6	1.0
Widowed	19	6.0	110	42.3	129	22.3
Employment status*						
Not working	9	2.8	29	11.2	38	6.6
Employed full time	27	8.5	8	3.1	35	6.0
Employed part time	19	6.0	10	3.9	29	5.0
Self employed	58	18.2	16	6.2	74	12.8
Retired	201	63.0	135	51.9	336	58.0
Housewife	314	98.4	61	23.5	61	10.5

*Significant difference between male and female group ($p \leq 0.05$)
Source: LRGS TUA Neuroprotective Model for Healthy Aging (Nik Mohd Fakhruddin *et al.*, 2016)

Table 3. Anthropometric characteristics and nutrient intake of the participants

Characteristics	*Male*		*Female*		*Total*	
	Range	*Mean±SD*	*Range*	*Mean±SD*	*Range*	*Mean±SD*
Height (cm)	144.0-183.6	161.9±6.4	136.0-167.7	151.0±5.8	136.0-183.6	157.0±8.2
Waist circumference (cm)	61.0-131.0	88.4±10.6	61.2 - 120.2	87.3±11.0	61.0-131.0	88.0±10.8
	Interquartile range	*Median*	*Interquartile range*	*Median*	*Interquartile range*	*Median*
Weight (kg)	14.6	63.0	14.6	58.0	16.1	60.6*
Body mass index (kg/m^2)	4.5	24.1	6.2	25.5	5.3	24.6*
Body fat percentage (%)	15.4	33.8	12.7	44.4	16.0	38.6*
	Interquartile range	*Median (RNI %)*	*Interquartile range*	*Median (RNI %)*	*Interquartile range*	*Median*
Nutrients						
Energy (kcal)	551.5	1691 (84.1)	505.5	1501 (84.3)	554.4	1622*
Protein (g)	26.2	70.2 (123.2)	20.8	65.2 (118.5)	23.9	68.5*
Carbohydrate (g)	97.5	229.3	71.3	195.6	86.9	215.0*
Fat (g)	21.0	51.8	23.8	48.8	22.0	50.3
Vitamin A (RE)	799.0	1022.0 (170.3)	822.4	992.9 (165.5)	806.6	1013.6
Vitamin C (mg)	89.2	96.4 (137.7)	105.7	101.8 (145.4)	95.4	99.0
Thiamine (mg)	0.4	0.8 (64.8)	0.5	0.7 (63.0)	0.5	0.7*
Riboflavin (mg)	0.5	1.2 (90.8)	0.6	1.1 (95.5)	0.6	1.1*
Niacin (mg)	5.3	10.0 (62.3)	4.4	9.8 (69.8)	4.6	9.9
Sodium (mg)	1065.5	1345.1 (89.7)	935.8	1037.2 (69.2)	988.1	1184.1*
Potassium (mg)	620.3	1391.6 (29.6)	717.3	1365.2(29.1)	674.2	1389.9
Calcium (mg)	240.6	473.4 (47.3)	301.0	471.1 (47.1)	274.2	472.1
Iron (mg)	6.3	13.138 (119.5)	6.2	11.7 (106.8)	6.5	12.5*

*Significant difference between male and female group ($p \leq 0.05$)
Normally distributed data were expressed in mean ± standard deviation while not normally distributed data were expressed in median and interquartile range

Table 4. Median score for each food category according to MDG (2011)

Food category		*TUA FNDI 9-1*	*TUA FNDI 9-2*	*TUA FNDI 8-1*	*TUA FNDI 8-2*	*TUA FNDI 7-1*	*TUA FNDI 7-2*	*TUA FNDI 9-1*	*TUA FNDI 9-2*	*TUA FNDI 8-1*	*TUA FNDI 8-2*	*TUA FNDI 7-1*	*TUA FNDI 7-2*
Calculation unit		*100 g*	*100 g*	*100 g*	*100 g*	*100 g*	*100 g*	*100 kcal*	*100 kcal*	*100 kcal*	*100 kcal*	*100 kcal*	*100 kcal*
Cereals, grains and tubers (*n*=16)	Median	0.4	0.4	0.3	0.3	0.4	0.4	2.0	1.9	1.6	1.6	1.9	1.9
	Interquartile range	1.2	0.5	1.2	0.5	1.2	0.5	5.9	2.6	6.0	2.5	5.9	2.6
Fruits (*n*=16)	Median	1.7	1.9	1.9	2.1	2.2	2.3	8.4	9.4	9.4	10.2	10.6	11.1
	Interquartile range	3.0	2.9	3.4	3.2	3.8	3.7	11.6	12.4	12.8	12.9	14.7	15.1
Vegetables (*n*=15)	Median	5.3	5.5	5.7	6.2	6.4	7.2	23.7	25.3	27.2	27.8	31.4	30.8
	Interquartile range	15.1	14.6	16.7	16.5	18.3	18.0	31.4	30.1	34.1	32.9	34.8	36.3
Fish, meat, poultry and beans (*n*=14)	Median	1.3	1.3	1.3	1.2	1.4	1.3	6.5	6.2	6.2	6.1	6.8	6.5
	Interquartile range	0.7	1.2	0.5	1.0	0.5	1.0	3.0	5.7	2.6	4.9	2.7	5.1
Milk and milk products (*n*=5)	Median	0.2	0.8	0.4	0.8	0.5	1.0	4.7	3.7	5.7	4.0	6.6	4.8
	Interquartile range	4.1	3.5	4.1	3.6	4.3	3.7	20.5	19.4	20.5	19.8	21.5	20.8
Fat, salt and sugar (*n*=15)	Median	-1.5	-1.8	-1.3	-1.6	-1.0	-1.3	-5.9	-8.1	-5.0	-8.2	-4.9	-8.2
	Interquartile range	9.6	3.9	9.4	3.7	9.2	3.6	65.0	31.0	64.7	30.7	64.6	31.1
Snacks and *kuih* (*n*=13)	Median	-0.6	-0.7	-0.6	-0.7	-0.6	-0.7	-2.9	-3.4	-2.8	-3.3	-2.8	-3.3
	Interquartile range	1.4	1.0	1.4	1.0	1.4	1.0	7.0	5.0	7.0	5.0	6.9	5.0

Table 5. Correlation of TUA FNDI nutrient profile models to energy density per 100 g of food

Model	*N*	*Correlation coefficient (r)*	*p*
TUA FNDI 9-1 (100g)	94	-0.676	<0.001
TUA_FNDI 9-2 (100g)	94	-0.715	<0.001
TUA FNDI 8-1 (100g)	94	-0.671	<0.001
TUA FNDI 8-2 (100g)	94	-0.711	<0.001
TUA FNDI 7-1 (100g)	94	-0.664	<0.001
TUA FNDI 7-2 (100g)	94	-0.709	<0.001
TUA FNDI 9-1 (100kcal)	94	-0.664	<0.001
TUA FNDI 9-2 (100kcal)	94	-0.712	<0.001
TUA FNDI 8-1 (100kcal)	94	-0.662	<0.001
TUA FNDI 8-2 (100kcal)	94	-0.709	<0.001
TUA FNDI 7-1 (100kcal)	94	-0.655	<0.001
TUA FNDI 7-2 (100kcal)	94	-0.708	<0.001

categorised as 'YES' and 36.2% was categorised as 'NO' by both MDG and TUA FNDI nutrient profiling model. A slight disagreement was shown, as there was 4.0% of food categorised as 'YES' according to TUA FNDI but categorised as 'NO' by MDG. Apart from that, 13.8% of food was categorised as 'NO' by TUA FNDI but categorised by 'YES' by MDG. However, these small disagreements did not affect the overall agreement level between MDG and TUA FNDI as indicated by kappa statistics, κ=0.644.

DISCUSSION

This study has successfully developed a nutrient profiling model, the TUA FNDI, in which vegetable and fruit groups had a higher median score compared to other food groups, owing to the presence of relatively higher amounts of vitamins and minerals. In contrast, "fat, salt and sugar" food groups contain relatively lower amounts of positive nutrients. This finding is in line with the results of Drewnowski *et al.* (2009) and Fulgoni *et al.* (2009). Models that included total fat showed higher correlation to energy density owing to fat contributing to a large portion of energy in the food.

An interesting finding obtained was that chicken liver showed a high score based on the TUA FNDI model, given its good source of nutrients namely, 100 kcal of chicken liver is equivalent to 86.2 g and provides the daily requirement of riboflavin (84.8% RNI), iron (62.6% RNI) and niacin (33.4% RNI) (Tee *et al.*, 1997). Fahmida & Santika (2016) reported chicken liver as a wholesome food that provides high amounts of nutrients at an affordable cost for low socioeconomic households in Indonesia. However, 100 kcal of chicken liver contains 492.4 mg cholesterol and very high vitamin A (750% RNI). The National Health Service (NHS) United Kingdom suggested liver or liver products should not be taken more than once per week (NHS, 2017).

Overall, the models were inversely correlated with energy density. Nutrient profiling has been shown to be an effective way to convey information regarding the nutritional attributes of foods to consumers (Miller *et al.*, 2009).

Although the 100 g formula is easier to be presented to the elderly, however, the lack of consistency in foods reported as 100 g, led us to select the 100 kcal unit in the final model. The 100 g formula is affected by the weight and water content of the food and this can influence the calculation of nutrient density score of food when calculated on weight basis (Drewnowski *et al.*, 2009). In contrast, the 100 kcal formula is not affected by water content and weight of the food (Sacks *et al.*, 2011). However, the 100 kcal formula may be harder to understand, especially among the elderly with low education level. Therefore, there is a need to convert the 100 kcal formula to 100g that is easier for the elderly to understand.

The validation was performed by comparing healthiness classification provided by MDG (NCCFN, 2010) and TUA FNDI nutrient profiling model. The results show substantial levels of agreement between both modes of classification. This shows the TUA FNDI nutrient profiling model can correctly categorise 'healthy' and 'less healthy' foods. This finding is in line with the results of Arambepola *et al.* (2008) and Wicks (2012). This study shows that TUA FNDI nutrient profiling model is a valid measure and can determine the nutrient density of food items correctly.

Nutrient profiling allows us to use numbers to portray the nutritional quality of foods in a holistic way and made it easier to understand (Di Noia, 2014; Alrige *et al.*, 2017). The score can be used as an educational tool by the health professionals and the elderly themselves to make better food choices that are rich in nutrients (Alrige *et al.*, 2017). Hence, nutrient profiling can be used as a tool to enhance the users' understanding about nutrition, enabling them to improve their dietary behaviour by avoiding diets that consisted of foods with low nutrient content (Alrige *et al.*, 2017).

The strength of this study lies in the development and testing of the model based on the nutritional needs of Malaysian elderly. Limitations include the lack of data on the contents of such negative nutrients as added sugar and saturated fats in the composition tables of foods consumed in Malaysia.

CONCLUSION

Overall, the TUA FNDI 9-2 model was able to categorise foods commonly consumed by the elderly according to nutrient density. Results from this study can be used by health professionals and by the elderly themselves as a reference for incorporating nutrient-dense food in their daily diet.

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Authors' contributions
RMB designed the methodology, conducted the data collection, data analysis and interpretation, wrote and revised the draft for the article; HMY involved in the methodology design, supervised the whole research, critically revised the draft and contributed ideas and expertise to improve the research; SS was the project leader and directly involved methodology design and fund acquisition of the research. She also supervised the whole research, critically revised the draft and contributed ideas for improvement.

Conflict of interest
We would also like to declare that there was no conflict of interest in writing this paper and conducting this research.

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