Mal J Nutr 28(2): 217-226, 2022

Formulation of local food multimix sprinkle to enhance nutritional adequacy of preschool children in southernmost provinces of Thailand

Laksana Chaimongkol & Bisri Soison*

Department of Food Science and Nutrition, Faculty of Science and Technology, Prince of Songkla University, Muang district, Pattani, 94000 Thailand

ABSTRACT

Introduction: This study aimed to formulate an effective Food Multimix-Sprinkle (FMM-S) by using locally available materials. **Methods:** Fish (Threadfin bream), cow liver, and orange fleshed sweet potato (OSP) were cooked and dried by using applicable household (HH) method and drum drying (DD). Then, the dried materials were milled and sieved through a 20 mesh screen. Fish, cow liver, and OSP sprinkles were mixed in various proportions to meet nutrient level targets [at least 30% of Thai Recommended Dietary Allowance (RDA) for 1-3 years old children per 15 g serving size]. **Results:** Six alternative mixes were formulated. The mixture of 3 g of liver, 7 g of fish, and 5 g of OSP (3:7:5) when processed by HH method, and the mixture of 4 g of liver, 8 g of fish, and 3 g of OSP (4:8:3) when processed by DD method, had significant advantage in preference scores in all attributes over the others. Nutritional values of these formulas were 37-55% RDA of protein, 146-194% RDA of vitamin A, and 30-40% RDA of iron for a serving size. **Conclusion:** This study demonstrated that household preparation, as well as preparation using drum drying could be used to process raw fish, cow liver, and OSP into a sprinkle mix. The FMM-S provided appropriate amounts of protein, vitamin A, and iron to supplement nutrient intake in pre-schoolers. However, a consumer test is needed to ensure acceptance by the target population.

Keywords: food multimix, nutritional formulation, sprinkle

INTRODUCTION

Nutritional deficiency during the first year of life significantly contributes to impaired growth and development of a child, which has long-term adverse effects. Suboptimal caregiver feeding practice is the most frequent factor inducing postnatal growth retardation (Branca & Ferrari, 2002). Inappropriate feeding of infants has been recognised as being practised in southern Thailand. Early introduction of complementary foods, feeding of sweetened condensed milk, late introduction of animal sourced foods, and inappropriate food choices are key issues (Mo-suwan & Sanguan-chua, 1980; Maisarow & Usaman, 1993; Bureau of Nutrition, 2006). In a preliminary survey of the dietary intake among children aged under 2 years in Pattani province (one of the three southernmost provinces of Thailand), it was found that children consumed a diet inadequate in some micronutrients,

*Corresponding author: Dr Bisri Soison
Faculty of Science and Technology, Prince of Songkla University,
Muang district, Pattani, 94000 Thailand
Tel: +668 5565 8208; Fax: +66 7333 5130; E-mail: baisri.s@psu.ac.th
doi: https://doi.org/10.31246/mjn-2021-0102

particularly iron, vitamin A, and vitamin B (Chaimongkol & Soison, 2012). Recently, it was found that 29.4% of children aged 6-59 months in the three southernmost provinces had low serum levels of vitamin A (Thammapalo *et al.*, 2020).

Caregivers are the key persons responsible for providing nutritionally qualified diets to children. In this geographical area, caregivers are mostly the mothers and sometimes the grandparents or relatives, or older siblings; and normally have no good grasp of an appropriate diet for this specific age group. Furthermore, they usually have no time because of busy daily schedule, including work. Most caregivers would rather buy ready-cooked foods or use the same food for their children as provided to adults in the family (household meals). Due to these constraints, it might be difficult to promote the cooking of foods that are specifically made to have appropriate nutrient proportions for young children (Chaimongkol & Soison, 2012). Therefore, food supplements might be an appropriate alternative strategy to enhance nutrient adequacy in this setting. There are various forms of food supplements, including food fortification, sprinkles, ready-to-eat foods, etc., which have their own advantages and disadvantages in terms of application to alleviate nutrient deficiencies. Choosing the right forms of food supplements for the context might determine the efficacy of this approach in solving the problem.

Food sprinkles are recognised as a means to improve the nutritional value of homemade baby foods. Sprinkles originated as a form of nutrient that can be easily mixed in any homemade foods. By sprinkling on the bulk food vehicles, these products provide dosing flexibility and convenience of administration, as well as cost-effectiveness (Lee *et al.*, 2020). As a home fortificant, sprinkles ensure that the food eaten contains adequate amounts of essential micronutrients. Furthermore, their use do not require any changes in other food practices; thus, they can be easily accepted in diverse cultural settings (Zlotkin *et al.*, 2005). Although food sprinkles have many advantages, there are some limitations to be considered in their application. Actually, nutrient sprinkles are not locally produced and are perceived as additive chemicals rather than as food, which might make them unacceptable, especially to low-income people. It was suggested that powdered local foods should be mixed to a sustainable super sprinkle (Nordin, 2005); hence, the idea of a food multimix (FMM) was introduced to cope with this issue. The FMM approach uses locally available, traditional and culturally adaptable complementary foods. Their review demonstrated that it is possible, in one composite mix, to provide a food recipe even in the midst of scarcity, to meet nutrient requirements through a food-based approach that is balanced, acceptable and appropriate within a cultural context. Products can be developed at a low cost, which can then be made easily available and affordable to most consumers (Zotor & Amuna, 2017). Thus, combining the concepts of sprinkle and FMM to formulate a “Food Multimix Sprinkle (FMM-S)” might be an approach to effectively enhance the adequacy of nutrients among pre-schoolers in southernmost Thailand.

In this study, we aimed to formulate FMM by using locally available ingredients, prepared in the form of sprinkles to provide additional nutrients, especially protein, vitamin A, and iron, to complement and complete the usual diet. Cow liver, fish, and orange fleshed sweet potato (OSP) were chosen as the FMM ingredients, since they are commonly consumed and available in the southernmost provinces. Cow liver

is a rich source of vitamin A and iron, while fish is a source of protein. OSP was included for its attractive colour and sweet flavour in the product. To make a suitable FMM-S, both locally applicable household method and drum drying method were used in processing to produce the ingredients mixed into formulas that were designed with proper nutritional proportions.

MATERIALS AND METHODS

Raw materials

The main raw materials used for sprinkles preparation were fish (Threadfin bream, *Nemipterus hexodon*), cow liver, and orange fleshed sweet potato (Khai variety, *Ipomoea batatas* L.). All were purchased from a local market in the Pattani province. Each material was freshly prepared according to the processing steps described below.

Raw material preparation

Fish fillets were obtained by removing the inedible parts, namely head, gut, scales and bones, and were steamed and later shredded into small pieces. Cow liver was cleaned, sliced into thin pieces, and soaked in 1.2% vinegar for two hours to reduce the liver flavour. After that, it was steamed for 30 minutes, set aside to cool, and then finely homogenised for one minute with a household grade food processor (Philips HR 1393/00, China). OSP was cleaned, peeled, sliced into 1-2 mm thin slices for frying in a household method, or chopped manually with a knife into small pieces for drum drying.

Production of sprinkles from main ingredients

Household (HH) method

Cooked fish and liver were roasted in a pan for approximately 20-30 minutes, or until dry and began to crumble. Sliced OSP was deep-fried in palm olein oil at 170±5°C until the pieces were cooked, then continued to dry in a hot air tray dryer (Kluay Num Thai Towop, Thailand) at 60°C for one hour. The moisture content of all ingredients was below 10% as determined by a moisture analyser (Sartorius MA150, Germany).

Drum drying (DD) method

Chopped OSP was steamed for 15 minutes and mashed before drying. All prepared raw materials were dried on a double drum dryer with settings of drum temperature at 130°C, gap between drums at 1 mm, and rotation speed at 1-2 rpm. The collected flakes were further dried in a tray dryer and their moisture content was controlled to be similar to the HH method. Dried fish, cow liver and OSP derived from both methods were milled and sieved through a 20 mesh screen for further use.

Formulation of FMM-S

Particle size of sprinkles

The dried ingredients were milled with a household blender and sieved to three fractions: (1) bigger than 8 mesh (over 2.36 mm), between 8 and 20 mesh (0.85 – 2.36 mm), and passing through 20 mesh (smaller than 0.85 mm). The optimum particle size for sprinkles was chosen by using a Just about right (JAR) approach. Finally, one particle size of each ingredient, prepared by each processing method was chosen.

Formulation of FMM-S

This product concept aimed to supplement nutrients that have a tendency to be deficit among pre-schoolers in the southernmost provinces, namely protein, vitamin A, and iron. The product should provide at least 30% of RDA per a typical serving size (15 g). Since the main target users of FMM-S were preschool children, the Thai Recommended Dietary Allowance (RDA) of protein, vitamin A, and iron used were those for children aged 1-3

years (Bureau of Nutrition, 2003). Three main components, namely fish, cow liver, and OSP sprinkles were mixed in various proportions to meet the nutrient targets. Thus, one serving contained 3 or 4 g of cow liver; 6, 7, or 8 g of fish; and 3, 4, 5, or 6 g of OSP to complete 15 g in total weight. By calculation using Microsoft Excel (Office Professional Plus 2016), six blends were formulated in this study. All formulas were subjected to colour measurement and sensory preference test. The most appropriate FMM-S formula was determined for its final quality characteristics of colour, moisture content, water activity, and TBA (thiobarbituric acid).

Colour and chemical property analyses

Colour

FMM-S formulas were measured by using Hunter Lab (Colour Quest XE, USA) for the colour coordinates L*, a* and b*.

Chemical analysis

Moisture, crude protein, fat and ash in the sprinkles were determined by official methods (AOAC, 2000). Water activity (a_w) was measured by using AQUALAB 4TE water activity meter (Meter Group, Inc., USA). Only cow liver was analysed for vitamin A and iron since it was recognised as an excellent source of these two nutrients. Vitamin A was determined by HPLC method (Kangsadalampai & Sungpuag, 1984), while iron content was analysed by Atomic Absorption Spectroscopy according to the methods of AOAC (Latimer, 2019). TBA was determined by the method of Egan, Kirk & Sawyer (1981).

Sensory evaluation

Just about right (JAR)

The 3-point JAR approach was used to determine the appropriate particle size for each sprinkle ingredient. Three sizes of each sample were served to 30 untrained panellists. They were asked to give their opinion on the particle fraction of sprinkles, whether it was too large, just right, or too small, by considering the overall size compared to the commercial rice seasoning sample (Proteilife, J.D. Food Products Co., Ltd.) as a control sample.

Preference test by hedonic scale

Samples of the alternative FMM-S were served with a bowl of porridge to 30 untrained panellists at the Food Science and Nutrition Department of Prince of Songkla University, Pattani campus. Sensory test of samples from each processing method was separately assessed. The panellists were asked to rate their preference scores on the attributes of the samples on a 9-point hedonic scale. The appearance, liver flavour, fish flavour, sweet potato flavour, overall flavour, and overall liking attributes of FMM-S formulas were evaluated. The Balanced Incomplete Block Design (BIB) was applied in the experiment by using plan 11.6, type II ($t = 6$, $k = 4$, $r = 10$, $b = 15$, and $\lambda = 6$) provided in a reference text (Cochran & Cox, 1992). Each formula was tested 40 times by some individuals among the panellists.

Ethics approval

The ethical committee of Prince of Songkla University, Pattani campus, approved the study protocols. All panellists were informed about the purpose of the study and procedures of sensory evaluation. Oral informed consent was obtained before performing product sensory evaluation.

Statistical analysis

All measurements were performed in triplicates. Statistical package R programme version 3.5.2 was used. Data were analysed using descriptive statistics and Analysis of Variance

(ANOVA). Post-hoc multiple comparison of means of different formulations was done by Duncan's multiple range test and considered statistically significant at $p \leq 0.05$.

RESULTS

Proximate composition of sprinkled ingredients

Fish, cow liver, and OSP were processed into coarse powder by household and drum drying methods. Protein contents were very high in fish and cow liver (70-90% and 58-68% dry basis, respectively). Only cow liver was analysed for vitamin A and iron. Vitamin A and iron contents in cow liver were 21,353 µg and 103 mg per 100 g dried ingredients, respectively (Table 1).

Effect of particle size fraction on properties of sprinkles

Moisture content in a food plays an important role in its spoilage. It is generally recommended that the moisture content in dried food should not exceed 15%. We found that the coarse powder of all three ingredients made by the two methods had a moisture range of 5.3 to 7.5% (Table 2). TBA is an indicator for the degree of lipid oxidation, as this liberates secondary oxidation products of oil and fat to the food. Most ingredients prepared by HH method had higher TBA than that prepared by DD method.

Formulation of FMM-S

Fish, cow liver, and OSP sprinkles were mixed in various proportions as shown in Table 3. The six FMM-S formulas were created from 3-4 g of cow liver, 6-8 g of fish, and 3-6 g of sweet potatoes. Protein, vitamin A, and iron contents per serving size (15 g) and %RDA were calculated for each formula (nutrient calculation based on dry weight). Estimated protein and iron in all formulas per one serving met one-third of the requirements, while the estimated vitamin A was 1.5 to 2 times the daily requirement. These amounts indicated that FMM-S has a high potential for being an effective food supplement of protein, vitamin A, and iron for young Thai children.

Colour

Appearance of FMM-S was evaluated from the L*, a* and b* colour coordinates. The results in Table 4 showed that each formula had a different colour, depending on proportions of the ingredients. Overall, the lightness (L*) of FMM-S was inversely related to the quantity of liver added, while the redness (a*) was directly related to the amount of OSP. When the proportion of cow liver increased, L* of FMM-S decreased. At the same time, if the proportion of OSP increased, a* significantly increased. When comparing between drying methods, DD resulted in the sample being more light-coloured,

Table 1. Selected nutrient contents (on dry basis) per 100 g in each of the three ingredients, when prepared by household (HH) and drum drying (DD) methods

Nutrient	*Fish*		*Cow liver*		*OSP*	
	HH	*DD*	*HH*	*DD*	*HH*	*DD*
Protein (g)	70.79±0.65	90.88±0.81	58.50±0.77	68.55±1.28	3.44±0.28	5.83±0.50
Fat (g)	1.54±0.09	2.69±0.22	6.95±0.24	14.81±0.15	11.13±0.32	0.18±0.03
Ash (g)	5.33±0.13	5.20±0.10	4.23±0.32	4.28±0.06	1.92±0.08	2.55±0.07
Vitamin A (µg)	na	na	21,353	na	na	na
Iron (mg)	na	na	103.09	na	na	na

na means 'not analysed'

Values are means of triplicate determination ± standard deviation

Table 2. Moisture content and TBA in fish, cow liver and OSP powder according to size fractions, prepared by using household (HH) and drum drying (DD) methods

Ingredient	*Size fraction (mesh)*	*Moisture (g/ 100g)*		*TBA (mg MDA/ kg)*	
		HH	*DD*	*HH*	*DD*
Fish	> 8	6.44±0.30	5.84±0.22	0.87±0.07	0.07±0.00
	8 to 20	5.48±0.21	5.78±0.24		
	< 20	5.30±0.24	5.93±0.34		
Cow liver	> 8	7.58±0.28	6.34±0.14	1.15±0.07	1.25±0.03
	8 to 20	7.58±0.35	6.52±0.30		
	< 20	5.78±0.10	6.08±0.32		
OSP	> 8	5.75±0.27	6.34±0.16	1.34±0.11	0.85±0.01
	8 to 20	5.36±0.11	6.32±0.13		
	< 20	6.81±0.02	6.74±0.25		

Values are means of triplicate determination ± standard deviation

redder, and less yellow than that of the HH method at the same mixture proportions.

Sensory Preference Test

Sensory evaluation results for the six FMM-S formulas prepared by HH method are shown in Table 5. The ingredient proportions in various FMM-S formulas significantly impacted the preference scores for the attributes of appearance, liver flavour, and fish flavour, but had no statistical effect on preference scores of sweet potato flavour, overall flavour, and overall liking (p>0.05). When considering all attributes, it was found that the formula with 4 g of liver, 7 g of fish, and 4 g of OSP (4:7:4) had significantly higher preference scores than the other formulas, but did not significantly

Table 3. Mixture proportions in FMM-S and calculated† amounts of protein, vitamin A and iron in each formula per one serving size

Proportions of ingredients (g/ 15g total) (liver:fish:OSP)	*Protein (g) (% RDA)‡*	*Vitamin A (µg) (% RDA)‡*	*Iron (mg) (% RDA)‡*
Formula 1 (3:6:6)	6.0 (33.4)	584.7 (146.2)	2.8 (30.3)
Formula 2 (3:7:5)	6.7 (37.3)	584.7 (146.2)	2.8 (30.3)
Formula 3 (3:8:4)	7.4 (41.2)	584.7 (146.2)	2.8 (30.3)
Formula 4 (4:6:5)	6.6 (36.6)	779.6 (194.9)	3.8 (40.3)
Formula 5 (4:7:4)	7.3 (40.5)	779.6 (194.9)	3.8 (40.3)
Formula 6 (4:8:3)	8.0 (44.5)	779.6 (194.9)	3.8 (40.3)

†Calculated nutrients by using the nutritional values of ingredients prepared by HH method
‡Values in bracket were calculated based on Thai RDA of preschool children aged 1-3 years, 2003 (Bureau of Nutrition, 2003)

Table 4. Colour coordinates of the tested FMM-S formulas

Method of processing	*Colour coordinate*	*Mixture proportions (liver:fish:OSP)*					
		3:6:6	*3:7:5*	*3:8:4*	*4:6:5*	*4:7:4*	*4:8:3*
Household (HH)	L*	43.3±0.6^{d}	45.8±0.7^{b}	48.0±1.4^{a}	44.7±0.8^{c}	42.8±0.6^{d}	44.9±1.6^{c}
	a*	11.1±0.6^{a}	10.4±0.5^{b}	9.5±0.8^{c}	10.1±0.9^{b}	8.5±0.5^{d}	7.1±0.7^{e}
	b*	32.5±0.6^{a}	31.5±0.9^{b}	31.2±1.5^{b}	28.8±0.6^{c}	27.5±0.9^{d}	26.7±1.0^{e}
Drum drying (DD)	L*	55.7±1.0^{a}	56.3±1.2^{a}	54.9±1.0^{b}	51.2±0.7^{c}	52.0±1.0^{c}	50.1±0.9^{d}
	a*	14.0±0.4^{a}	13.2±0.7^{b}	11.8±0.5^{c}	11.2±0.6^{c}	10.4±0.2^{d}	8.9±1.0^{e}
	b*	30.8±0.5^{a}	30.2±0.9^{a}	28.6±0.6^{b}	26.8±0.8^{c}	26.1±0.6^{c}	24.6±1.0^{d}

$^{a-e}$ Mean values ± standard deviation with different superscripts in the same row indicate statistically significant differences at $p \leq 0.05$

differ ($p>0.05$) from the 3:7:5 formula in all attributes. Since increasing liver powder use in the product would affect the commercial production cost, the formula of 3:7:5 was selected as a suitable FMM-S mix to be prepared by HH method. Nutritional values of this formula were 37% RDA of protein, 146% RDA of vitamin A, and 30% RDA of iron in 15 g of FMM-S.

Sensory results for the six FMM-S formulas prepared by the DD method are shown in Table 5. Again, the ingredient proportions significantly affected the preference scores for all attributes ($p \leq 0.05$). Increasing liver and fish portions caused the scores for liver and fish flavour to increase; and as expected, the score for sweet potato flavour decreased. Overall, the formula of 4:8:3 had a significantly higher score in all attributes than the others ($p \leq 0.05$). Therefore, this formula was considered suitable for preparing FMM-S by the DD method. Nutritionally, this formula provided 55% RDA of protein, 194%

Table 5. Preference scores of six FMM-S formulas from sensory evaluation

Attribute	*FMM-S formula (liver:fish:OSP)*					
	3:6:6	*3:7:5*	*3:8:4*	*4:6:5*	*4:7:4*	*4:8:3*
By household method						
Appearance	6.2±1.1^{cd}	7.3±0.9^{ab}	6.2±1.4^{cd}	6.8±1.0^{bc}	7.8±0.8^{a}	6.1±1.4^{d}
Liver flavour	6.1±1.5^{c}	6.4±1.2^{bc}	7.0±0.9^{a}	6.1±1.2^{c}	6.9±0.8^{ab}	5.9±1.4^{c}
Fish flavour	6.0±1.6^{c}	7.3±1.2^{a}	6.8±1.4^{ab}	6.3±1.5^{bc}	7.3±0.9^{a}	7.3±1.0^{a}
Sweet potato flavour	6.2±1.4^{a}	6.3±1.4^{a}	6.3±1.3^{a}	6.8±1.4^{a}	6.7±1.0^{a}	6.5±1.1^{a}
Overall flavour	6.6±1.0^{a}	6.5±1.3^{a}	6.2±1.3^{a}	6.2±1.6^{a}	6.5±1.0^{a}	6.4±1.3^{a}
Overall liking	6.5±0.9^{a}	6.5±1.4^{a}	6.3±1.4^{a}	6.3±1.5^{a}	6.9±1.1^{a}	6.3±1.3^{a}
By drum drying method						
Appearance	5.3±1.4^{c}	6.3±1.4^{b}	5.9±1.5^{bc}	6.5±1.5^{b}	6.5±1.4^{b}	7.3±1.3^{a}
Liver flavour	5.8±1.3^{b}	5.8±1.5^{b}	5.7±1.6^{b}	6.0±1.4^{ab}	6.3±1.5^{ab}	6.7±1.3^{a}
Fish flavour	5.8±1.0^{b}	6.2±1.2^{ab}	6.1±1.5^{ab}	5.9±1.2^{b}	6.4±1.5^{ab}	6.6±1.2^{a}
Sweet potato flavour	5.5±1.6^{b}	5.9±1.7^{ab}	6.2±1.3^{ab}	5.9±1.4^{ab}	6.3±1.3^{a}	6.4±1.5^{a}
Overall flavour	5.6±1.4^{b}	6.5±1.3^{a}	6.5±1.4^{a}	6.2±1.4^{ab}	6.9±1.5^{a}	6.7±1.2^{a}
Overall liking	5.7±1.2^{b}	6.2±1.3^{ab}	6.3±1.4^{ab}	6.3±1.5^{ab}	6.4±1.7^{ab}	6.5±1.4^{a}

$^{a-d}$ Mean values ± standard deviation with different superscripts in the same row indicate statistically significant differences at $p \leq 0.05$

RDA of vitamin A, and 40% RDA of iron per 15 g serving.

The total cost of producing a 15 g FMM-S was estimated, which included ingredients, instruments, personnel, and supplies for a batch processing. It was approximately 22 THB for the HH method and 23.5 THB for the DD method, respectively. The production cost might decrease when production capacity is increased. Lower cost will be preferable for the target population who has low income.

DISCUSSION

Household method and drum drying method were chosen to process raw materials to dried- ground powder since the application of FMM-S strategy might occur through two approaches, i.e., local or industrialised manufacturing. Local production is superior to industrialised production in terms of community involvement, which leads to the sustainability of the programme. Furthermore, it can facilitate income generation in a community as well.

The selected local materials for making FMM-S, i.e., fish (Threadfin bream) and cow liver contained significantly high amounts of protein. One gram of dried fish and cow liver had 0.7-0.9 g and 0.6-0.7 g of protein, respectively (Table 1). Protein and fat contents in cow liver and fish processed by the HH method were slightly lower than those processed by the DD method. The unexpected differences may have occurred due to differences of food sample matrix according to processing method. Raw materials prepared by HH method were exposed to high temperature for a long time during roasting, which was a more severe processing procedure in comparison to drum drying processing. This can result in the destruction, denaturation, or oxidation of molecule structures in food components. Consequently, this may lead to lower levels of protein and fat extraction of materials treated by HH method in comparison to DD method. In addition, different batches of raw materials were used in processing for the two processing methods.

Generally, liver is a good source of vitamin A and iron, but not fish. Vitamin A content of the local cow liver in this study (21,353 µg/100 g) was at the high range in comparison to prior studies that indicated the range of vitamin A content to be from 3,699 to 22,945 µg/100 g dry basis. Varied vitamin A content depends on the age and breed of cow, as well as the nutritional quality of its feed (Majchrzak, Fabian & Elmadfa, 2006). Thus, fish powder can serve as a source of protein, while cow liver as a source of vitamin A and iron, as well as of protein. OSP is known as a source of carotenoids. Bengtsson *et al.* (2008) found that the mean trans-β-carotene content in seven different OSP genotypes ranged between 108 and 315 µg/g dry basis. Therefore, OSP can be considered an excellent source of pro-vitamin A, and it can provide some additional vitamin A even if not as much as cow liver.

The two key factors to be controlled for prolonging the shelf-life of dried foods are moisture content and lipid oxidation. According to Table 2, there were similar moisture content among different particle sizes and processing methods, but TBA values of fish and OSP powder prepared by HH method were much higher than those prepared by DD method, probably because of the high temperature and long time in processing. In addition, the study of Lee & Yoon (2013) found that heating time and mean particle size of sample significantly affected its TBA. However, these ingredients still had lower TBA values, on top of lower moisture content levels compared to the standard dried product.

Size of particles has a direct effect on the acceptability of the sprinkles. Majority of panellists (70-89%) agreed that the particle size ranging from 8 to 20 mesh of each ground material was just the right size, comparable to the commercial rice seasoning sample (data not shown). Thus, this size was chosen to formulate FMM-S. The mixture of liver, fish, and OSP at 3:7:5 was selected as a suitable FMM-S mix to be prepared by HH method, while the formula of 4:8:3 was considered suitable for preparing FMM-S by the DD method. Nutritional analysis findings of these FMM-S formulas suggested that consumption of 2 servings (30 g) a day is able to fulfil the protein, iron, and vitamin A requirements of preschool children. Even though 30 g of FMM-S will provide about 300-400% RDA of vitamin A, which seems quite high, this level is far lower from the daily toxic dose of 1,212 µg/kg body weight for 6-15 months old children (WHO, 2021). However, product acceptance among target consumers need to be further investigated.

Water activity and moisture content of the selected FMM-S processed by HH method were 0.51±0.01 and 7.18±0.31%, respectively; while FMM-S processed by DD method had an a_w of 0.48±0.01 and moisture content of 6.77±0.25%. These values were in accordance with the quality standards of the Thai Community Product Standards: Seasoning fish powder (TCPS 1337/2549) (TISI, 2006) and with rice seasoning standard for a seasoning powder, which specified a range of 0.60 – 0.65 for a_w and moisture content not exceeding 13% (TCPS 494/2547) (TISI, 2004). Thus, these FFM-S formulas in dried forms with quite low a_w and moisture content do not require refrigeration. However, storage test should be performed to determine the optimal conditions of the product, particularly on how humidity, light, and climate change may affect product quality during storage.

CONCLUSION

This study demonstrated that household method or alternatively drum drying method can be used to process raw fish, cow liver, and OSP into dried ground sprinkles. The mixture of cow liver, fish, and OSP sprinkles at a ratio of 3:7:5 (prepared by HH method) or 4:8:3 (prepared by DD method) were the most acceptable in sensory evaluation. One serving of these formulas (15 g) is able to add protein and iron at approximately 30-55% RDA, and vitamin A at 150-200% RDA for preschool children. A consumer test would be needed to ascertain the acceptance by the target population.

Acknowledgements

All panellists are acknowledged for their voluntary participation and good cooperation in the sensory evaluation of the products. The authors are grateful for the research funding provided by Halal Food Science Centre, Faculty of Science and Technology, Prince of Songkla University, Thailand.

Authors' contributions

LC, designed the experiments, performed the statistical analysis and data visualisation, and wrote the manuscript; BS, designed and conducted all of the experiments and wrote the manuscript. All authors have read and approved the final manuscript.

Conflict of interest

The authors declare that they hold no competing interests.

References

AOAC (2000). *Official Methods of Analysis*. 17th ed. The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Bengtsson A, Namutebi A, Alminger ML & Svanberg U (2008). Effects of various traditional processing methods on the all-trans-β-carotene content of orange-fleshed sweet potato. *J Food Compos Anal* 21:134-143.

Branca F & Ferrari M (2002). Impact of micronutrient deficiencies on growth: The stunting Syndrome. *Ann Nutr Metab* 46(1):8-17.

Bureau of Nutrition (2003). *Dietary Reference Intake for Thais 2003*. 4th ed. Ministry of Public Health, Nonthaburi. (in Thai)

Bureau of Nutrition (2006). *The Fifth National Nutrition Survey of Thailand*. Ministry of Public Health, Nonthaburi. (in Thai)

Chaimongkol L & Soison B (2012). *Development of Nutritious Local-Recipes for Children Aged 6-24 Months in Southernmost Provinces*. Faculty of Science and Technology, Prince of Songkla University, Pattani. (in Thai)

Cochran WG & Cox GM (1992). *Experimental Design*. 2nd ed. John Wiley & Sons, Inc., New York.

Egan H, Kirk RS & Sawyer R (1981). *Pearson's Chemical Analyses of Foods*. 8th ed. Churchill Livingston, London.

Kangsadalampai K & Sungpuag P (1984). *Laboratory Manual for Food Analysis*. Institute of Nutrition, Mahidol University, Nakhonpathom.

Latimer WG Jr (2019). *Official Methods of Analysis of AOAC International*. 21th ed. AOAC International, Maryland, USA. Method No. 984.27

Lee HS, Lee JJ, Kim MG, Kim KT, Cho CW & Kim DD (2020). Sprinkle formulations: A review of commercially available products. *Asian J Pharm Sci* 1:292-310.

Lee YJ & Yoon WB (2013). Effects of particle size and heating time on thiobarbituric acid (TBA) test of soybean powder. *Food Chem* 138:841–850.

Maisarow B & Usaman S (1993). *Thai Muslim Infant Care Behavior In Southern Thai Border Region*. M.Sc. Dissertation. Prince of Songkla University, Songkhla Thailand. (in Thai)

Majchrzak D, Fabian E & Elmadfa I (2006). Vitamin A content (retinol and retinyl esters) in livers of different animals. *Food Chem* 98:704-710.

Mo-suwan L & Sanguan-chua P (1980). *Infant Feeding Practice among Southern Thai Population*. Department of Pediatric Medicine, Faculty of Medicine, Prince of Songkla University, Songkhla. (in Thai)

Nordin S (2005). Sustainable super-sprinkle: Powdered local foods. *PLOS Med* 2(7):e188. doi: 10.1371/journal.pmed.0020188.

TISI (2004). *Thai Community Product Standards: Seasoning Powder*. (TCPS 494/2547). Thai Industrial Standards Institute, Ministry of Industry, Bangkok. (in Thai)

TISI (2006). *Thai Community Product Standards: Seasoning Fish Powder*. (TCPS 1337/2549). Thai Industrial Standards Institute, Ministry of Industry, Bangkok. (in Thai)

Thammapalo S, Boonamnuaykij B, Chantutanon S, Pichensophon S & Sangsawang C (2020). A survey on prevalence and risk factors for vitamin A deficiency among children under 5 years old in southern border provinces, Thailand, 2019. *J Health Sci* 29(3):400-408. https://thaidj.org/index.php/JHS/article/view/9196

WHO (2021). *In: Adverse Events Following Administration of Vitamin A Supplements*. From https://cdn.who.int/media/docs/default-source/immunization/intervention/adverse_events_vita.pdf?sfvrsn=9f783ae6_3 [Retrieved December 13 2021].

Zlotkin SH, Chauer C, Christofi des A, Sharieff W & Tondeur M (2005). Micronutrient sprinkles to control childhood anaemia. *PLOS Med* 2:e1. doi:10.1371/journal.pmed.0020001

Zotor FB & Amuna P (2017). The food multimix concept: Harnessing and promoting local composite complementary diets. *Proc Nutr Soc*