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EDITORIAL

The Journal of Nutrition and Food Sciences (J. Nut. Food Sci.) is the official peer-reviewed publication of the Nutrition Society of Sri Lanka. We are pleased to launch the journal at the time the Nutrition Society of Sri Lanka celebrates its fiftieth anniversary. The journal also sets a record becoming the first ever periodical originated in Sri Lanka that publishes scholarly work in nutrition or food science.

A surge of research in the fields of nutrition and food science was observed in the recent past in Sri Lanka as well as in rest of the Asia. However, there has not been many dedicated journals that publish both nutrition and food science related research outcomes. The Journal of Nutrition and Food Sciences was initiated to set a platform for researchers to publish research output in nutrition and food science and to stimulate research across diverse areas of nutrition, food science and technology.

The journal is happy to consider high quality manuscripts for publication that focus on applied food and nutrition research. Original research, review articles, short communications, case reports and case series in nutritional and food sciences and allied fields are considered for publication in the journal. The journal will initially be published twice a year online and subsequently the frequency of publishing can be increased depending on the demand.

As editors-in-chef, we wish to acknowledge the authors for their contribution and the reviewers for sparing time in evaluating the manuscripts. We also thank the office bearers and members of The Nutrition Society of Sri Lanka for providing us the opportunity to prepare the journal and assisting us in numerous ways. It is our fervent hope that we will be able to emerge as a journal of high quality that disseminate knowledge in nutrition and food science.

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Macronutrient Composition of Popular Snacks Available at Food Outlets in Sri Lanka

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ABSTRACT

Background: Non-Communicable Diseases (NCDs) account for 75% of deaths in Sri Lanka. Most common causes for NCDs include poor diets and physical inactivity. The majority of snacks available in the food outlets are calorie-dense, thus lack of vitamins and minerals. Continued consumption of calorie-dense snacks may lead to certain NCDs. In Sri Lanka, only commercially packed foods provide information on the nutritional composition. However, foods available in sales outlets lack such nutritional information which is vital for health-conscious consumers.

Objectives: This study aimed at identifying the total energy and the macronutrient composition of popular snacks available for sale at food outlets in Sri Lanka.

Materials & Methods: Thirty (30) popular snacks were identified from 18 food outlets in Sri Lanka. The data on the recipes, raw ingredient weights and final cooked weight were collected. Energy and macronutrient compositions of one serving size of the snacks were analyzed using Food base 2000 software.

Results: The total energy supplied by one serving size of snacks ranges from 46 to 436 kcals. Mean calorie contribution by carbohydrate, protein and fat were 58.5%, 9.4% and 32.1%, respectively.

Conclusions: Most of the snacks available in the outlets were of high-calorie density and are based on carbohydrates providing more than the expected calorie contribution to the consumer.

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INTRODUCTION

World Health Organization (WHO) predicts that 71% of global deaths are due to NCDs. Non communicable diseases are the most prominent health problem in Sri Lanka during the past two decades (Jayawardena et al., 2014) and this epidemic is partially associated with the unhealthy dietary habits of the population. Diet-related chronic diseases are predicted to be increased up to 40% by 2025, globally (Fareeza, 2011). According to WHO, unhealthy diets are one of the major risk factors which are responsible for NCDs. Diet with high calories and fat cause insulin resistance leads to type 2 diabetes mellitus (T2DM). The development of hypertension in adolescents occurs due to the unhealthy lifestyle including excessive intake of total, and saturated fat, cholesterol and salt, inadequate intake of potassium etc (Aboderin et al., 2002). The nutrition transformation of the traditional diet to a Western diet is one of the causes for the occurrence of NCDs (Weerasekara et al., 2018). The quality of dietary fat appears to be affected when the energy from fat is high (greater than 37% of total energy) (WHO & FAO, 2003). Studies have shown that about 33% of cancers, 80% of coronary heart disease and 90% of T2DM incidence could potentially be avoided through changing lifestyle factors such as eating healthy and engaging in adequate physical activity thereby maintaining normal weight throughout life (Hu et al., 2001; Key et al., 2002). Unhealthy diets have a positive relationship with the metabolic risk factors for NCDs in the undergraduate population (Olatona et al., 2018). Consumption of nutrient-dense foods and low energy-dense foods contribute to reducing the risk factors associated with cardiovascular disease and T2DM (Iriti et al., 2020). Snacks are defined as small foods consumed between the main meals (FAO). The frequency of snacks consumed per day has increased over the past decades with increased urbanization. Most of the snacks available in the outlets in Sri Lanka are fried and rich in carbohydrates and fats. Some studies define snacks as energy-dense, nutrient-poor foods, which are rich in sodium, sugar and or fats (Wang et al., 2012; Duffey et al., 2013; Lipoeto et al., 2013; Bellisle, 2014). Due to the increased calorie density and poor nutrient quality often snacks are considered unhealthy foods (Yeo et al., 2020). The contribution of snacks towards energy consumption in men and women are 17 and 21% respectively (Myhre et al., 2015).

Nearly 70% of Sri Lankan adults exceed the recommended level of daily starch intake (Jayawardena et al., 2013). People tend to compromise the intake of leafy vegetables, fruits, yams, meat, eggs, fish and dairy products due to the rise of prices of these items (Nimanthika et al., 2018). In case of snacks, majority of the population prefer to buy snacks from food outlets rather than making them at home due to the busy lifestyle. Most of the snacks which are purchased from outlets are calorie-dense and high in carbohydrates and fats.

Most of the commercially packed foods in Sri Lanka include nutritional information on its label. However, the snacks prepared in ordinary food corners lack nutritional information. People are unaware of the calorie density of these snacks they consume. Long-term consumption of unbalanced and calorie-dense snacks lead to the development of NCDs. However, there are no reported studies that have been done in Sri Lanka regarding the nutritional composition of popular snacks available in local food outlets. Presence of such information would help the consumer to choose their snacks according to their calorie preference and the health condition. Therefore, this study focused on identifying the energy and macronutrient composition of popular snacks available at the food outlets in Sri Lanka.

MATERIALS & METHODS

Data collection

Data were collected from selected food outlets and food producers located in Jaffna, Kurunegala and Gampaha districts based on convenience. Nine (09) locations from Jaffna, six (06) from Kurunegala and, three (03) from Gampaha were selected. Owners of food outlets participated in the interviews. Snacks were selected based on popularity, availability and on the ethnic background of the country. Some small-scale shops do not prepare the snacks in their kitchen, and they used to purchase snacks from other food producers. With the help of food outlets operators, original food producers were contacted to collect data. Weight of raw ingredient lists, recipes and final weight of the selected thirty snacks were collected from food outlets and food producers. When snacks were prepared by several outlets, data of the raw ingredient lists were collected from all food outlets. Highly deviated (if different ingredients were added which are not included in other recipes) data were removed. The average weight of ingredients from other ingredient lists was calculated and taken for the analysis. Snacks which were taken into the analysis were "Bajjie", "Boli", "Bonda", "Boonthi laddu", "Chicken bun", "Susiyam", "Egg rolls", "Fish pastry", "Fish patties", "Fish rolls", "Jam bun", "Kaddlae vada", "Kesari", "Kollukattai", "Lavaria", "Maalu paan", "Mashmallow", "Mothakam", "Muscat", "Omlet bun", "Palkova", "Pani appa", "Potato roti", "Sausage bun", "Sausage pastry", "Ulundhu vada", "Vaipan", "Vattalappam", "Vegetable patties" and "Vegetable rolls".

Snacks were freshly prepared by using collected raw ingredient lists and recipes in the Dietetic Laboratory, Department of Applied Nutrition, Wayamba University of Sri Lanka. The actual amounts of oil used to fried snacks were measured. Nutrient retention factors were not applied by assuming that macronutrients do not lose during heating or other processing steps as this study was limited to analyzing the energy and macronutrient composition of selected snacks. The weight of the edible portion was measured for required items from the collected raw ingredients. The portion size of each snack was determined using the data collected from the food servers in each selected food outlet. Data on the usual number of similar types of snacks consumed by consumers at a time were collected and the average consumption number was calculated and round off to zero decimal point. That was considered average consumption. The data were also analyzed for one portion size of selected snacks.

Data analysis

"Foodbase® 2000" software was used to analyze the data of the energy and macronutrient composition of the studied snacks. The raw ingredient list and weight of each edible raw ingredient to prepare one serving size of snacks were calculated and tabulated. All the calculated raw ingredients to make one serving size of the snacks were entered into the "Foodbase® 2000". The energy and the macronutrient composition of each snack were calculated using the recipe calculation method.

RESULTS

One snack (item) was considered as one serving size of a snack. The weight of one serving size was taken as an average weight of 10 similar snacks. Table 1 shows the serving sizes of selected snacks. Table 2 shows the energy and macronutrient composition of one serving size of selected 30 snacks for the study.

Table 1. Serving sizes of selected snacks (based on mean and standard deviation)

Snack	Serving size (g) †	Snack	Serving size (g) †	Snack	Serving size (g) †
Bajjie	19	*Jam bun*	65	*Palkova*	42
Boli	76	*Kaddlae vada*	32	*Pani appa*	58
Bonda	55	*Kesari*	66	*Potato roti*	83
Boonthi laddu	46	*Kolukattai*	94	*Sausage bun*	88
Chicken bun	138	*Lavaria*	83	*Sausage pastry*	55
Susiyam	52	*Maalu paan*	122	*Ulundhu vada*	40
Egg roll	73	*Marshmallow*	12	*Vaipan*	62
Fish pastry	48	*Mothakam*	78	*Vattalappam*	60
Fish patties	54	*Muscat*	102	*Vegetable patties*	61
Fish roll	71	*Omlet bun*	91	*Vegetable rolls*	72

†The serving size is based on the mean and standard deviation

Table 2. Energy and macronutrient composition per one serving size of snacks

Snack	Energy (kcals)	Carbohydrate (g)	Protein (g)	Fat (g)
Bajjie	107	7.2	1.4	8.3
Boli	274	45.6	6.6	8.5
Bonda	135	9.9	1.4	10.3
Boonthi laddu	149	18.7	3.5	7.3
Chicken bun	312	34.8	11.3	15.2
Susiyam	139	16.2	3.3	7.2
Egg roll	172	26.5	5.2	5.8
Fish pastry	116	16.6	4.2	4.2
Fish patties	104	16.9	2.7	3.3
Fish roll	161	27	4.6	4.6
Jam bun	162	34	2.7	2.6
Kaddlae vada	96	7.7	3.5	5.9
Kesari	252	42.9	2.9	8.8
Kolukattai	173	30.3	4.9	4.4
Lavaria	123	23.1	1.4	3.5
Maalu paan	368	62.5	11.1	10.0
Marshmallow	46	11.4	0.8	0.0
Mothakam	148	26	4.6	3.6
Muscat	436	63.6	2.8	20.6
Omlet bun	177	28.4	6.1	5.1
Palkova	157	20.1	4.7	7.0
Pani appa	106	17.3	1.0	4.1
Potato roti	118	26.6	3.7	0.4
Sausage bun	185	28.9	5.7	5.9
Sausage pastry	139	17.2	4.3	6.4
Ulundhu vada	141	15.6	6.2	6.4
Vaipan	238	38.3	3.1	9.0
Vattalappam	129	21.5	2.7	4.2
Vegetable patties	130	21.1	2.9	4.3
Vegetable rolls	154	24.4	3.2	5.5

Table 3. Percentage of calorie contribution by macronutrients per serving of snacks

Snack	Carbohydrate (%)	Protein (%)	Fat (%)
Bajjie	26.4	5.1	68.5
Boli	63.9	9.3	26.8
Bonda	28.7	4.1	67.2
Boonthi laddu	48.4	9.1	42.5
Chicken bun	43.3	14.1	42.6
Susiyam	45.4	9.2	45.4
Egg roll	59.2	11.6	29.2
Fish pastry	54.9	13.9	31.2
Fish patties	62.5	10.0	27.5
Fish roll	64.4	11.0	24.7
Jam bun	79.9	6.3	13.7
Kaddlae vada	31.5	14.3	54.2
Kesari	65.4	4.4	30.2
Kolukattai	67.2	10.9	22.0
Lavaria	71.4	4.3	24.3
Maalu paan	65.0	11.6	23.4
Marshmallow	93.4	6.6	0.0
Mothakam	67.2	11.9	20.9
Muscat	56.4	2.5	41.1
Omlet bun	61.8	13.3	25.0
Palkova	49.6	11.6	38.8
Pani appa	62.9	3.6	33.5
Potato roti	85.3	11.9	2.9
Sausage bun	60.4	11.9	27.7
Sausage pastry	47.9	12.0	40.1
Ulundhu vada	43.1	17.1	39.8
Vaipan	62.1	5.0	32.8
Vattalappam	63.9	8.0	28.1
Vegetable patties	62.7	8.6	28.7
Vegetable rolls	61.0	8.0	31.0

Table 4. Portion sizes and average number of portions of snacks

Snack	Average portion number	Portion size (g)	Snack	Average portion number	Portion size (g)
Bajjie (Banana)	2	38	*Lavaria*	2	166
Bonda	2	110	*Marshmallow*	3	36
Susiyam	2	104	*Mothakam*	2	156
Egg roll	2	146	*Pani appa*	2	116
Fish pastry	2	96	*Potato roti*	2	166
Fish patties	2	108	*Sausage pastry*	2	110
Fish roll	2	142	*Ulundhu vada*	2	80
Kaddlae vada	2	64	*Vaipan*	2	124
Kolukattai	2	188	*Vegetable patties*	2	122

(Snacks with the same portion size and serving size are not included in the table)

Macronutrients supplied by one serving size of snacks were in the range of carbohydrate (7.2 g - 63.6 g), protein (0.8 g - 11.3 g) and fat (0.0 g - 20.6 g).

The energy density for one serving size shows a huge deviation among snacks. “Muscat” had the highest calorie density while “Marshmallow” had the lowest. “Muscat” supplied the highest amount of carbohydrates while “Bajjie” was the lowest. “Bonda”, “Kadallae vada” and “Bajjie” provide less than 10 g of carbohydrate for one serving size. These commonly used snacks were not good sources of protein. One serving size of a snack that provides the highest amount of protein was a chicken bun. “Muscat” supplied the highest amount of fat per portion.

The snacks tested in this study supplied a higher calorie through carbohydrate and fat. Table 3 shows the percentage of calorie contribution of each snack from carbohydrate, protein and fat. Calorie (energy) contribution through carbohydrates varies from 26.4 to 93.4%. Eighteen out of thirty snacks provide more than 60% of calories from carbohydrate. Calorie contribution through protein was comparatively low (2.5 - 17.1%). Except for “Ulundhu vada”, all other snacks provide less than 15% of calories through protein (“Uludu vada” is a pulse-based product). Calorie contribution through fat varies from 0% to 68.5%. Fifteen of the tested snacks provide more than 30% of calories through fat.

Calorie density varies from 46 to 436 kcals per serving of selected snacks. Except for two, all other snacks provide more than 100 kcals. But the portion size may vary from one snack to another, and it depends on the type, size, taste and individual preference of snacks. Table 4 shows the average portion size of a few selected snacks. The calorie density of one portion size of snacks ranged from 138 to 476 kcals.

Individual calorie and nutrition intake were not dependent on serving size. It was dependent on the portion size/ quantity of snacks consumed by the person at a time. Considerable changes were observed in nearly two thirds (2/3) of snacks in their portion size, nutritional composition when compared to serving size, while they remained the same with the rest of snacks.

DISCUSSION

Regular consumption of snacks may lead to higher calorie intake and subsequently increase the risk of NCDs in the long run. If the average calorie intake is considered as 2000 kcals, consumption of a single portion of these snacks provides energy in the range of 6.9 to 23.8%. When considering the 30 snacks, the mean calorie supplied by one portion size of snack is 257.96 kcals. It is 12.9% of the daily calorie intake of a person if he or she consumes the snack available in the marketplace as the only snack. However, Sri Lankans usually consume tea or other beverages in combination with more than one snack. This signifies the regular trend of higher calorie consumption. The guidelines developed for a healthy canteen at the workplace by the Ministry of Health, Sri Lanka indicates that calorie distribution per snack time (morning snack/evening snack) as 1/10 of the daily calorie intake (Ministry of Heath, Sri Lanka., 2013). However, the mean calorie contribution by the snack with one serving was 12.9% according to the present study. It is 2.9% higher than the requirement of calorie for a snack time. If any other beverage is consumed with that calorie consumption is increased further. If a person consumes snacks regularly, that increases the daily calorie intake leading to the development of NCDs in long-term. Some commonly consumed bakery items like “Mallu paan” provides 368 kcals per snack. This is about 18.4% of the total daily calorie intake which is double the required amount. Many adolescents and school children consume bun items like “Mallu Paan” as their common snacks which increase the calorie intake to a significant level. Mean calorie contribution by carbohydrate, protein and fat were 58.5%, 9.4% and 32.1%, respectively. The majority of the studied snacks were calorie-dense, high in carbohydrate and fat and low in protein.

Similar research carried out on thirty Chinese New Year (CNY) snacks shows that the energy density of twenty-one CNY snacks was in the range of 2011 kJ/100 g (~ 481 kcals) to 2743 kJ/100 g (~656 kcals). In a 100 g of the snacks, the carbohydrate content ranged from 4.5 g - 85.3 g, protein content ranged from 0.1 g - 42.6 g and the fat content ranged from 7.7 g - 51.9 g (Yeo et al., 2020). An Indian research showed unhealthy fat content of snacks in low-socioeconomic settings in India. According to their study, total fat and trans-fat content in 100 g of Samosaa (which is similar to vegetable patties) were 29.62 g - 10.35 g, 24.01 g - 10.25 g in Fan (similar to pastry puffs), and 31.99 g - 11.67g in Kachori (deep-fried, salted, puffed bread made of wheat flour) respectively. Fat content of most of these snacks was in the range between 25-30% and few snacks identified with more than 50% of fat content (Gupta et al., 2016). In comparison to selected Sri Lankan snacks fat content in the Indian street snacks are high.

Based on the guidelines for healthy canteen in workplace and the daily average calorie requirement of 2000 kcal, one portion size of snacks that provide more than 200 kcals are considered as high-calorie snacks. Based on the recommendations by the Institute of Medicine for the National Academics of USA, average contribution for total daily energy intake from carbohydrate, protein and fat should be 45 - 65%, 10 - 35% and 20-35% (Institute of Medicine-USA, 2002). One portion size of snacks supplying more than 27.5 g of carbohydrates are considered as high in carbohydrate; when there is more than 5.0 g of fat are considered as high in fat and when supplies less than 13.75 g of protein are considered as low protein. Out of the selected snacks more than half of the snacks provide high amount of carbohydrate and fat and low amount of protein than the recommended range.

Inability to generalize the findings of the study due to limited island-wide representation and convenient sampling are limitations of the study. However, the findings of the present study provide basic understanding of the calorie density and macronutrient composition of the popular snacks available at the food outlets in Sri Lanka.

CONCLUSIONS

Selected snacks available in the food outlets in Sri Lanka are high in calories, carbohydrate, fat, while low in protein. The mean calorie supply by a snack at one serving is higher than the recommendations of the local guidelines.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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Meal Composition and Temporal Eating Patterns among Sri Lankan Adults: A Cross-sectional Study

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ABSTRACT

Background: Understanding population-specific food consumption patterns is useful for controlling diet-related health complications.
Objectives: This cross-sectional study aimed to identify the meal composition and timing of the meals among the public in Sri Lanka.
Materials & Methods: A nationally representative sample of adults was selected using a multi-stage random cluster sampling technique. Meal pattern data was derived from 24-hour dietary recalls.
Results: Almost all the surveyed respondents consumed three major meals, breakfast (97.6%), lunch (97.9%), and dinner (99.0%). Only 31.8% and 36.2% of the population had mid-morning and evening snacks, respectively. Vegetables were not consumed by 73.2%, 44.1%, and 58.2% of participants for breakfast, lunch, and dinner, respectively. Rice was the most common breakfast food item (67.7%), of which, 10% of participants consumed rice only with *'coconut sambol'*. Only 8.9%, 30.4%, and 11.8% of participants incorporated green leafy vegetables in their breakfast, lunch, and dinner in that order. Meat or meat equivalents were consumed by 28.8%, 60.8%, and 52.4% of participants for breakfast, lunch, and dinner, respectively. The most common snacks were biscuits/confectionaries and bakery foods. The time range between wake-up and breakfast was 00:30-07:00 hh: mm (Mean: 03:03 ± 1:17) while it was 00.15-05:45 hh: mm (Mean: 1:50 ± 0.56) between dinner and sleep onset.
Conclusions: The majority of the study population's meals are not deemed healthy and lack of variation in all dietary groups, including fruits, vegetables, dairy, meat or meat equivalents, and pulses. Biscuits, confectionaries, pastries, and other starchy foods were the most common snacks. There was a significant variation in meal timing among these groups.

INTRODUCTION

It is widely recognized that a nutritionally sound diet is fundamental to human health and well-being across the lifespan (WHO, 2009). A poor diet contributes to poor health and is a well-established, modifiable risk factor for the development of non-communicable diseases (NCDs), which are leading causes of global deaths (WHO, 2009). Over 80% of the global NCD deaths have occurred in low and middle-income countries (WHO, 2018). Sri Lanka is in the advanced phases of a demographic transition and is undergoing a fast epidemiological and nutritional revolution (De Silva, 2013). Regardless of micro-nutrient deficiencies, which are still reported in some parts of the country (World Bank, 2007), NCDs are emerging as the major diet-associated health concerns in Sri Lanka (Swarnamali, Jayasinghe and Katulanda, 2017). An increasing body of evidence has linked diet with the risk of developing NCDs, such as obesity, type 2 diabetes, cardiovascular diseases, and certain types of cancers (Cespedes and Hu, 2015). These conditions are aggravated by a range of various dietary risk factors such as low consumption of fruits and vegetables, and excess consumption of saturated fat, trans-fat, sugar, and salt (WHO, 2014).

Identification of dietary components that may play a role in the prevention of NCDs has become a major concern for researchers and public health authorities. People consume a combination of food components as meals rather than individual food components or nutrients. Hence, the recent approach in nutrition research is based on the identification and analysis of dietary or food consumption patterns of the general public (Cespedes and Hu, 2015). Dietary guidelines also focus on diet diversity with a high intake of fruits, vegetables, whole grains, and legumes; moderate intake of low-fat dairy and seafood; and low in processed meats, sugar-sweetened beverages, and refined grains (USDA, 2015). Therefore, it is important to evaluate the meal composition of adults in Sri Lanka to understand whether their food selection is health-promoting.

In addition to the above facts, irregularity of meal timing is now reported as another potential risk factor for metabolic syndrome, diabetes mellitus, and cardiovascular disease (Garaulet and Madrid, 2010). Besides, it has also been reported that late-night dinner is associated with obesity, metabolic syndrome, and hyperglycemia (Wang et al., 2013). This is because, glucose tolerance is reduced in the evening, from a combination of reduced glucose utilization, decreased insulin sensitivity, and low insulin secretion (Ruxton and Kirk, 1997). However, a lack of understanding of the timing of food consumption among Sri Lankan adults may lead to inappropriate management methods in the control of metabolic complications associated with meal timing. Therefore, the main objective of this cross-sectional study was to identify dietary patterns including meal composition and meal timing among the public in Sri Lanka.

MATERIALS & METHODS

Study sample

Participants for the present study were recruited based on the sample from the Sri Lanka Diabetes and Cardiovascular Study (SLDCS), a national study conducted between 2005 and 2006. In brief, the eligible respondents of this cross-sectional study were healthy Sri Lankan adults aged ≥ 18 years recruited from a sub-sample of a Sri Lanka Diabetes and Cardiovascular Study (Katulanda et al., 2008). In this study, a total of 500 subjects were selected representing all nine provinces using a multi-stage random cluster sampling technique consisting of 100 clusters according to the probability-proportional-to-size method, to gain a representative sample from the nine provinces. The sample was then stratified based on the area of residence and ethnicity. Those who were pregnant, lactating, acutely ill or on a therapeutic diet were excluded. Written informed consent for participation in the study was obtained and ethical approval for this study was taken from the Ethics Review Committee, Faculty of Medicine, University of Colombo, Sri Lanka (EC/10/126). Details of the sample selection have been published previously (Jayawardena, Byrne, Soares, Katulanda and Hills, 2013).

Data collection procedure

An interviewer-administered questionnaire was used for data collection. Information relating to sociodemographic factors and the timing of daily routines (bedtime, wake-up time, and mealtime) was obtained. Bodyweight, height, and waist circumference were measured using standard protocols (WHO, 2017) and all these measurements were conducted by a trained staff member. Height was taken to the nearest 0.1 cm using a calibrated stadiometer (SECA GmbH & Co. KG, Hamburg, Germany). Body weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale (SECA GmbH & Co. KG, Hamburg, Germany). The standard formula, weight (kg) divided by height (m^2), was used to calculate the body mass index (BMI), and cut-offs were presented as recommended by WHO experts for Asian populations (WHO, 2004). Waist circumference was measured to the nearest 0.1 cm using a measuring tape.

Assessment of dietary intake

Dietary data were gathered using a 24 h dietary recall in direct chronological order. The intake of main meals (breakfast, lunch, and dinner) was divided into standard food groups such as cereal or equivalents (starchy foods), vegetables, pulses, meat or equivalents, green leafy vegetables, and fruits. Foods that were not considered in any of the above food groups were considered in the 'other' category. Details of the intake of drinks/beverages were also collected. The detailed methodology regarding the translation of food into the respective food groups is submitted in the supplementary file 1(https://nutritionsocietyofsrilanka.org/wp-content/uploads/2023/02/Supplementary-file..pdf).

The timing of all meals was recorded. Dietary recalls were collected by two trained nutritionists who had received uniform training and adhered to the standard operating procedure (SOP). Dietary recalls of each participant were conducted by both data collectors separately. To minimize the inter-personal variation, at the end of the day the two interviewers reviewed each other's work and maintained homogeneity of the recording procedure. Where there was a disparity in the dietary recalls, participants were re-contacted for the second time and the 24h dietary recall was repeated on a different day.

Data analysis

Data were analyzed using SPSS version 20 (SPSS Inc., Chicago, IL). Mean values with standard deviations (SD) and range were used to describe the study sample whereas, meal and sleep timing distributions were presented as mean ± SD and range (minimum and maximum values). The correlations between continuous variables were analyzed using Pearson correlation. The independent t-test was performed to determine the association between continuous variables. The significant association between variables was determined using inferential statistics based on a p-value of less than 0.05.

RESULTS

Table 1 summarizes the demographic characteristics of the study sample, meal timings, and circadian variables. The mean ± SD age of the population was 48.20 ± 14.62 years. The majority of the population was female (65.5%). Most of the study participant (35.8%) had a normal BMI, while 16% were found to be overweight, 34.4% were obese and 13.9% were underweight according to the WHO cut-off values for Asian populations. The mean ± SD of BMI was 22.87 ± 4.05 kg/m^2.

Table 1. Demographics, mealtime, sleep, and circadian characteristics of the participants

Parameter	n	Mean ± SD	Range
Age (years)	488	48.20 ± 14.62	18.0 - 89.0
BMI (kg/m^2)	489	22.87 ± 4.05	13.54 - 37.03
Waist circumference (cm)	488	78.81 ± 1.03	55.9 - 109.2
Sleep and circadian variables†			
Bedtime (hh:mm)	434	22:06 ± 0:58	19:00 - 02:00
Wake-up time (hh:mm)	482	05:15 ± 0:54	02:30 - 10:00
Sleep duration (hours)	433	07:05 ± 0:70	02:30 - 12:00
Mealtime†			
Wake-up drink (hh:mm)	451	06:04 ± 0:55	03:10 - 11:00
Breakfast (hh:mm)	474	08:17 ± 1:04	05:30 - 11:30
Lunch (hh:mm)	475	13:44 ± 0:58	11:00 - 17:30
Dinner (hh:mm)	474	20:18 ± 0:56	17:30 - 23:45
Time gap			
Breakfast-wake-up (hh:mm)	470	03:03 ± 1:17	00:30 - 07:00
Bedtime-dinner (hh:mm)	421	01:50 ± 0:56	00.15 - 05:45

†*24-hour clock time. MI = Body mass index, n = Sample size*

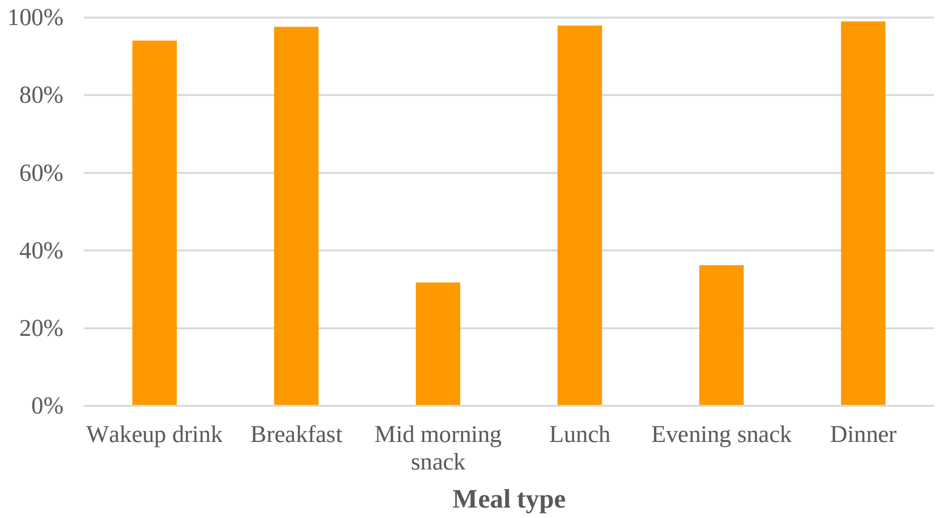

Figure 1. Consumption of meals by the participants on a given day

The meal timing, sleep and circadian variables are presented in Table 1.

Figure 1 depicts the percentage of the population that consumed three major meals (breakfast, lunch, and dinner), a wake-up drink, and in between two snacks. Almost all the participants had three main meals: breakfast (97.6%), lunch (97.9%), and dinner (99.0%).

In terms of proportion of the study sample who consumed a variety of wake-up drinks apart from water (considering the drinks which supplied substantial calories), full cream milk powder added tea (53.0%, n=256) was the most common wake-up drink and the second most common drink was 'plain tea' (tea without milk) (26.1%, n=126). A very small proportion of the population consumed fresh milk (2.1%, n=10). Moreover, only 16.3% (n=66) of the participants consumed a snack with wake-up drink and of which biscuit was the commonly consumed snack (12.1%, n=49) among them.

In terms of breakfast (n = 460); 2.4% (n = 11) of participants did not consume a breakfast. Starch-based breakfast was consumed by 96.3% (n = 443) of the sample while the rest of them had a pulse-based meal (1.3%, n = 6). Figure 2 has summarized an overview of the selection of different food options for their breakfast. Amongst starch-based food options, rice (69.9%, n=310) was the main choice and bread (11.3%, n=50) was the second option. When considering the consumption of vegetables, 73.2% (n=327) of respondents did not consume any form of vegetable for their breakfast. The proportion of people who obtained meat or meat equivalents for their breakfast was 28.8 %(n=128). Among them, dried fish/sprats (15.5%, n=69) and fish (7.7%, n=34) were found to be the most common items while a few of them consumed eggs (3.2%, n=14) and chicken (1.6%, n=7). Nine-tenths of participants (91.1%, n=409) did not add any green leafy vegetables for their breakfast. Nearly half of the study sample (48.0%, n=232) incorporated pulses for their primary starch-based breakfast, and dhal (32.8%, n=151) was the main type of pulse used by them. Only 11.9% (n=49) of them added fruits for their breakfast, from which banana was the most common fruit type (10.2%, n=42). Approximately a quarter of the population (24.3%, n=118) consumed *'coconut sambol'*, and 10.6% (n=51) of them consumed only the *'coconut sambol'* with rice or string hoppers without adding anything from other food groups.

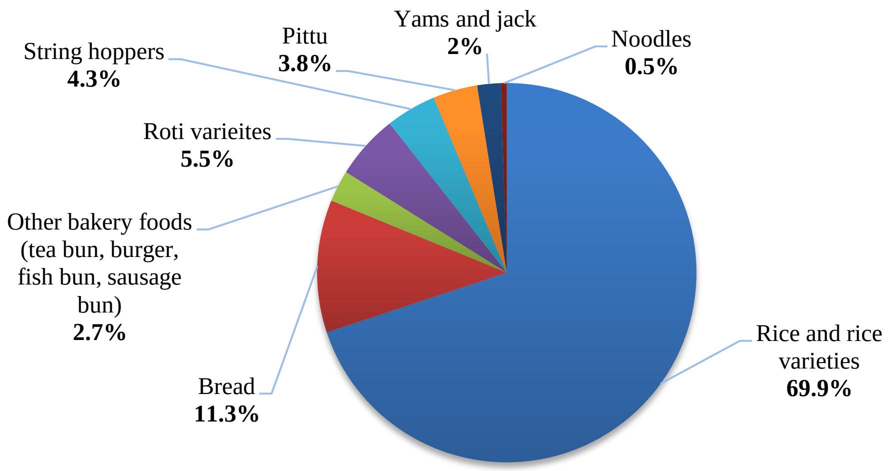

Figure 2. Breakfast meal options of the participants

Of the participants who consumed any kind of mid-morning drink (47.4%, n=229), almost all had 'plain tea' (46.1%, n=223). Nearly one-third of the population (31.8%, n=153) added some sort of snack along with the above drinks. Moreover, biscuits and confectionaries were the most common type of snacks (15.8%, n=76), while starch-based bakery foods were the second most common snack (12.9%, n=62). Only 2.8% (n=14) and 0.4%(n=2) consumed fruits and dairy products as mid-morning snack, respectively. In relation to lunch, rice with curies was the most common meal type (97%, n=460). The rest of the population (3%, n=14) consumed bread or biscuits, or other bakery foods as lunch. Nearly half of the participants (44.1%, n=209) did not consume any vegetables for their lunch. There were 60.8% (n=288) of participants who consumed any meat or equivalent for their lunch. According to Figure 3 majority of the participants obtained dried fish/sprats (25.3%, n=120) and fish (23.2%, n=110) as meat or equivalent. Nearly half of the study sample (46.3%, n=224) added pulses to their lunch, with dhal being the most consuming pulse type (40.5%, n=196). Green leafy vegetables were consumed by 30.4% (n=147) of the respondents for their lunch, while fruits were consumed by only 15.7% (n=76).

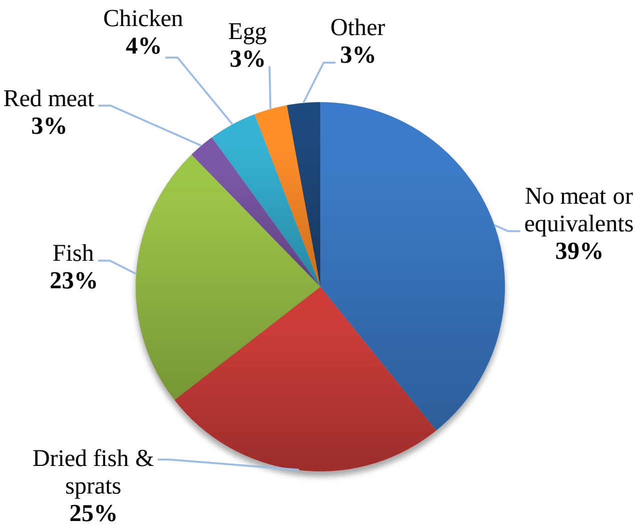

Figure 3. Consumption of meat or equivalents during lunch

Snacking behaviour during the evening is summarized in Figure 4. Of the participants who consumed any type of evening drink (77.9%, n=376), the majority of them consumed *'plain tea'* (49.4%, n=238) while 24.6% of them consumed full cream milk powder added tea (n=119). Biscuits (18.4%, n=89) or sweets (6.5%, n=32) or *'short eats'* (4%, n= 19) were first, second and third most common options for evening snack respectively while fruits were consumed only by 4.3% (n=21) of participants.

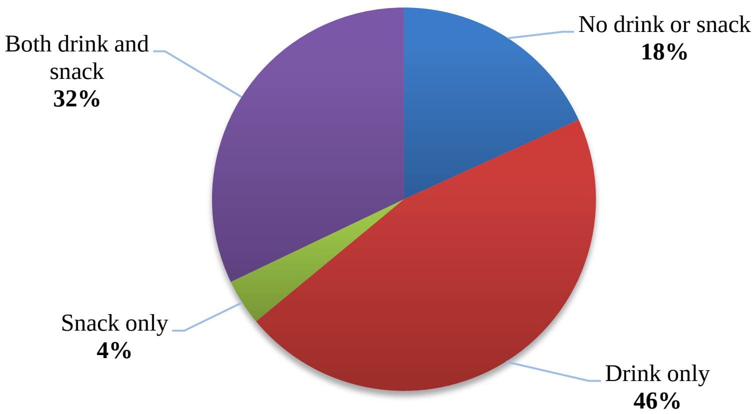

Figure 4. Snacking behavior in the evening

Considering the dinner (n=482); rice or rice-based recipes (79.3%, n=382) was the most common option while the rest of the participants consumed bread and other bakery foods (6.6%, n=32), *'pittu'* (5.2%, n=25), string hoppers (4.8%, n=23), 'roti' (2.3%, n=11) noodles and *'kottu'* (1.4%, n=7) and another type of starchy foods (0.4%, n=2). Thirty percent (n=146) of the participants added a second starchy food, while 6.6% (n=31) included a third starchy food in addition to rice as the primary starchy food. More than half of the study sample (58.2%, n=276) did not eat any vegetables at dinner. Participants who consumed meat or equivalents (52.4 %, n=253) mostly had dried fish/sprats (21.9%, n=106) or fish (17.8%, n=86), while only 5.4% (n=26) consumed chicken, 1.9% (n=10) had red meat, and 4.6% (n=22) consumed eggs. Dhal (32.2%, n=155) was the main pulse among the participants who consumed pulses 38.6% (n=189) for their dinner. Green leafy vegetables were consumed only by 11.8% (n=57) while fruits were consumed by 12.2% (n=59) of the participants for the dinner.

The results of the correlation analysis of the body measurements and time gap between breakfast and waking up time and the time gap between bedtime and dinner are presented in Table 2. There was no statistically significant correlation between body measurements and the time gap from waking up to breakfast and dinner to bedtime in this sample.

Table 2. Correlation between body measurements and time gap from breakfast to wake-up and dinner to bedtime.

Variable	n	r	p
BMI-time gap from waking up to breakfast	470	0.077	0.094
WC-time gap from waking up to breakfast	470	0.045	0.329
BMI-time gap from dinner to bedtime	429	0.097	0.054
WC- time gap from dinner to bedtime	429	0.065	0.178

BMI = Body mass index, WC = Waist circumference n=Sample size, r= Correlation, p=Significance level

DISCUSSION

Population-specific food consumption patterns provide valuable insights into the health-related risks prevailing in the country. This is the first cross-sectional study to our knowledge, identifying dietary patterns including food composition and meal timing of Sri Lankans.

Nearly three-quarters of the population did not consume any vegetables for breakfast, while nearly half of them did not have any vegetables for lunch and dinner. This indicates the undesirable circumstance in terms of vegetable consumption in the population as a whole. Nearly three-quarters of the participants did not consume any meat or meat equivalent for their breakfast, also nearly two-fifth of them did not consume it for lunch and dinner. Additionally, dried fish and sprats were the first most common meat or meat equivalent source while fish was the second most common option during all three main meals. Nevertheless, eggs, chicken, and red meat consumption was very low among this group. Similarly, a previous study which was done in one particular rural area of Sri Lanka also demonstrated that fresh fish and dried fish were the most consumed meat or equivalent option (Siriwardhana et al., 2014). Further, eggs, chicken, and red meat consumption were less common according to them (Siriwardhana et al., 2014) which is consistent with our results. However, Western diets were characterized by the high intake of animal products including red and processed meat (Pan et al., 2012). It was identified that consuming at least small amounts of meat or equivalents such as chicken, eggs and red meat could be an essential source of protein and micronutrients particularly in lower-income countries where diets lack diversity (Kearney, 2010). Therefore, our attention should be focused on enhancing meat or equivalent consumption in every meal. Pulses were not consumed by more than half of the study participants for all three major meals, and also dhal was the most common pulse type in their meals. Consumption of green leafy vegetables was also not favorable among this study group because only one-tenth of the population consumed it in each meal. According to a study carried out in South Korea, intake of vegetables and pulses was found to be more significant in the groups with a higher level of knowledge on nutrition (Jo et al., 2013). Therefore, it is acknowledged that improving awareness on nutrition through education or consultation is required to increase their consumption of the aforementioned food groups, consequently promoting diet diversity (Jayawardena, Byrne, Soares, Katulanda, Yadav, et al., 2013).

One-third of the population had mid-morning and evening snacks. This indicates that having snacks between main meals was not common among this group. Having snacks all day long is likely to affect hunger at subsequent meals (Gayle Savige, Abbie MacFarlane, Kylie Ball and Crawford, 2007). Hence, this group might be most likely to reduce their snacks either as a conscious decision or as a result of increased satiety because almost all the participants consumed breakfast and lunch which may diminish their sense of hunger through in-between meals. In the present survey, biscuits, confectionaries, pastries, and other starchy foods were the most common types of snacks, whereas fruits were consumed by a small number of participants for mid-morning and evening snacks. Fruit consumption, on the other hand, was not complimentary during main meals. Reasons behind selecting those types of foods instead of fruits for snacks may be due to the low cost, convenience, flavorful and satisfying nature of the those snacks due to high sodium (salt) content. However, as those foods are prepared with low-cost ingredients such as refined grains, sugar, and fats instead of nutritious ingredients such as whole grains, fruits, vegetables, and dairy, it is harmful to consume those foods regularly, because eating them too much over a long period can lead to health issues such as high blood pressure, heart diseases, and unwanted weight gain. Recent systematic reviews and meta-analyses also have shown that low fruit and vegetable intake are common among South Asians (Jayawardena et al., 2020). The low intake of fruits was recorded as the third leading dietary risk factor for nearly 2 million deaths and 65 million disability-adjusted life-years globally (Afshin et al., 2019). Therefore more attention needs to be paid to realistic modifications of dietary choices in preventing NCDs.

No individual was taking dairy products during their main meals. Only two participants consumed it for their mid-morning snack but none of them consumed any dairy product for their evening snack. According to the previous findings, the main reason for the lower consumption of dairy food is the high cost of dairy products (Kubicová, Predanocyová and Kádeková, 2019). The dairy food requirement of this study group was fulfilled primarily through the most common drink at wake-up, full cream milk powder added tea which was prepared by mixing powdered milk with 'tea' which affects the absorption of calcium to the body from the milk (Gueguen and Pointillart, 2000). However, for the mid-morning and evening drink, almost all participants drank ‘plain tea’ (tea without milk). Evidence suggests that tea appears to be safe without significant side effects and protects against several forms of cancer, bacterial infections, and dental caries (Trevisanato, 2001). Although polyphenols in tea reduce the bioavailability of non-haem iron, tea only inhibits this iron absorption when it is concurrently consumed with a meal containing non-haem iron (Trevisanato, 2001).

According to the present analysis, there was no significant association between BMI or waist circumference (WC) and the time gap between waking up and breakfast as well as the time gap between dinner and sleep. However, it has been previously found that eating later and closer to sleep onset has an impact on metabolic dysfunction since insulin response to evening meals is lower, and thus, glucose levels remain high over a longer period (Buxton et al., 2012). There was a considerable variability among participants in the timing of the first meal to waking up and the last meal to bedtime. For example, while the average time for breakfast was 8:17 a.m., breakfast might be taken as early as 5:30 a.m. or as late as 11:30 a.m. Furthermore, the average duration between morning drink and getting up was 3 h, although the range was 30 min to 7 h. In addition, the average last meal was at 8:18 p.m., although it ranged from 5:30 p.m. to 11:45 p.m. Although the timing of food intake was found to be related to obesity and the success of weight-loss therapy (Garaulet and Gomez-Abellán, 2014), the association between mealtime and body measurements was not meaningful in the current study due to the significant time variability.

There were several limitations in this study. Although a one-day 24-h dietary recall is appropriate to estimate population mean intakes in a cross-sectional study, future research should include multiple days and detailed information about the quantity of each food taken during each meal. However, due to logistic and infrastructural constraints, it was not possible to include more recalls. Future research needs to consider conducting a national food intake survey comprising the detailed composition of both qualitative and quantitative data over the day to enhance the understanding of Sri Lankan dietary practices.

CONCLUSIONS

The meals consumed by the majority of the study population is unhealthy and lack of variation across all food categories including fruits, vegetables, green leafy vegetables, dairy, meat or equivalents, and pulses. In each of the three major meals, a significant proportion of the research group preferred rice with dhal curry. Biscuits, confectionaries, pastries, and other starchy foods were the most common types of snacks, whereas fruits were consumed by a small number of participants as snacks. Fruit consumption, on the other hand, was not complimentary during main meals too. Although almost all the participants consumed the three main meals, there was a significant variation in meal timings.

CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

SUPPLEMENTARY MATERIAL

For supplementary material referred to in this article, please visit the journal website: https://nutritionsocietyofsrilanka.org/the-journal-of-nutrition-and-food-sciences-2/

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Formulation and Characterization of a Healthy Snack with a Low Glycemic Index

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ABSTRACT

Background: The rate of starch digestion and glycemic response are influenced by the composition of food.

Objectives: To formulate a healthy snack utilizing locally accessible ingredients and to determine the energy and macronutrient composition of the snack, the glycemic index, insulinemic index, and *in vitro* starch digestibility properties of the carbohydrate fractions of the snack and its main ingredients, which may be important in predicting the *in vivo* responses.

Materials & Methods: A healthy snack was formulated using Olu rice, foxtail millet, barley, and chickpeas as main ingredients, together with wheat flour, cinnamon, butter, raisins, egg white, baking powder and vanilla essence. Laboratory analysis was carried out to achieve the objectives.

Results: The proximate compositions of protein, fat, soluble dietary fiber, insoluble dietary fiber and digestible starch in g/100g were 12.35 ± 0.77, 15.00 ± 0.36, 3.47 ± 0.31, 1.8 ± 0.45 respectively with 441.8 kcal energy. The fiber content of the formulated healthy snack had a higher soluble fiber to insoluble fiber ratio. The starch digestion index (SDI) of the four main ingredients ranged from 21.60 to 38.50. The predicted glycemic indices (pGI) of the ingredients varied from 24.69-41.49, whereas the pGI of the formulated snack was 43.69 and the actual glycemic index was 36.5. All these values fell within the low GI category of foods.

Conclusions: A healthy snack with a low glycemic index can be prepared with locally available food items ensuring the cultural acceptability of Sri Lankans.

INTRODUCTION

Snacks often fail to deliver expected standards from a health promotion standpoint. They are often made with refined ingredients with added fiber. Taste, appearance, and texture modifiers are extensively used to meet the healthy snacks palatable and appealing. Furthermore, due to the increase in access to global markets, ingredients may be imported, leaving out local ingredients with inherent healthful properties. The cultural acceptability of a product rests largely on the ingredients used. With increasing prevalence of chronic diseases and their links to increasing energy, fat, sugar and salt consumption, the need for developing healthy snacks is rising.

The benefit of low glycemic index (GI) diets is now well-documented, in both diabetic and non-diabetic populations. The rate of starch digestion and its resulting glycemic response are significantly influenced by the composition of food, such as the content of resistant starch, phosphorylated starch, phytonutrients, dietary fiber, protein, and the fat content (Absar et al, 2009). The interaction of starch with fiber, protein and other food components can affect the diffusion and adsorption of the starch digestive enzymes (Colonna et al, 1992) and will affect the GI following ingestion of the food. Fat in a meal delays gastric emptying and reduces the rate of absorption of glucose and the rise in post-prandial insulin. It reduces starch gelatinization thereby slowing down digestion and absorption of glucose and subsequently lowering the GI (Absar et al, 2009). Hence, the postprandial insulin responses are not always proportionate to the blood glucose concentrations or the total carbohydrate content of a meal. Therefore, it essential to estimate the GI of the composite food made with a mixture of ingredients.

A low glycemic index snack is indicative of one that is more healthful than a high glycemic index snack due to a higher fiber content as well as higher protein, complex starches and will invariably provide more micronutrients. Such a snack would be within recommendations for the diabetic population to improve glycemic control and also for the general population in preventing type 2 diabetes and help in weight loss (Thomas and Elliott, 2010).

In-vitro methods focus on the sensitivity of carbohydrates to digestive enzymes (Englyst and Cummings, 1985). *In-vitro* starch digestibility assays are a good predictor of the *in-vivo* glycemic response of starchy foods (Englyst et al., 2003). *In-vitro* methods can be used to classify starch into rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) (Englyst and Hudson, 1996). The *in vivo* method to determine the GI of foods is laborious, time consuming and requires the co-operation of motivated volunteers. Therefore, several *in vitro* methods which mimic the physiological digestion of carbohydrate foods have been developed. Most of the *in vitro* methods focused on analyzing basic foods (Englyst et al., 1999; Englyst et al., 2000; Englyst et al., 2003; Garsetti et al., 2005). Therefore, the prediction of GI by these *in vitro* methods would be of immense practical use. Other factors that influence glycemic response are the methods of cooking and processing of food and its interaction with other food components.

The aim of this study was to formulate a healthy snack consisting of locally accessible ingredients and to determine the energy and macronutrient composition of the snack, the glycemic index, insulinemic index, and *in vitro* starch digestibility properties of the carbohydrate fractions of both the snack and its main ingredients, which may be important in predicting the *in vivo* responses.

MATERIALS & METHODS

Chemicals

5.0 g/L pepsin (Sigma)
0.01M HCl
5.0 g/L guar gum (Sigma)
0.25 M sodium acetate buffer
4.0 g/L Pancreatin (Sigma)
Amyloglucosidase (sigma)
Human glucose liquicolour, complete test kit (Human GmbH)
2 M KOH

Preparation of the healthy snack

A healthy snack was formulated using pre-decided quantities of Olu rice (26 g), foxtail millet (26 g), barley (26 g), and chickpeas (20 g) as main ingredients together with wheat flour (20 g), cinnamon (1 teaspoon), butter (32 g), raisins (40 g), egg white (33 g), baking powder (1 teaspoon) and vanilla essence (1 teaspoon). All ingredients were purchased locally in bulk. The quantity of each ingredient and the final recipe was determined based on maintaining the physical properties of the cookie dough and were fine tuned to maintain the macronutrients within recommendations of EASD (European Association for the study of diabetes). The said ingredients were selected based on scientific reference to these being beneficial to those with type 2 diabetes mellitus (DM) (Narayanan *et al.,* 2016, Minaiyan *et al*., 2014, Nestel *et al.,* 2004).

Olu rice, foxtail millet (*Setaria italic*), barley (*Hordeum vulgare L.*), wheat flour, chickpea (*Cicerarietinum*), cinnamon, baking powder, raisins, butter, vanilla and egg white with water were made into a dough, shaped into balls (8-10 g each) and baked at a temperature of 150^{o}C for 20 minutes.

Protocol for determination of glycemic index and insulinemic index

Participants

Ethical approval (EC 15-069) for the study was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Colombo. Informed written consent was obtained from all the participants prior to the study. Twelve healthy volunteers (six males and six females) aged between 25 and 65 years with normal BMI (18.5-24.99 kg/m^2) were selected for the study. Inclusion criteria for the selection of participants were being non-smokers, non-alcoholics, not on any form of medication, non-pregnant or non-lactating, with a normal fasting blood glucose level (70 to 100 mg/dL). Individuals with DM were excluded. Height and weight of the study participants were measured according to the National Health and Nutrition Examination Survey, Anthropometry Procedures Manual (NHANES, 2007).

Determination of GI and insulinemic index

Determination of GI and insulinemic index was carried out according to the method described by FAO/WHO (FAO/WHO, 1998). Following an overnight fast of 10-12 hours, a sample of venous blood was collected for fasting blood sugar testing (2.0 mL blood in a fluoride oxalate tube) and insulin (3.0 mL blood in a plain tube). Subsequently, the participants were given 250.0 mL of glucose solution (55 g of glucose dissolved in 250.0 mL water; corresponding to 50 g available carbohydrate) to be consumed within 10-15 minutes. Venous blood samples were drawn at 15, 30, 60, 90 and 120 minutes after glucose consumption for blood sugar analysis. After a break of one week, participants were called back for the determination of GI of the test food. Participants were requested to consume the test food containing 50 g available carbohydrate within 10-15 minutes. Blood samples were drawn at 15, 30, 60, 90 and 120 minutes after test food consumption.

All the blood samples were centrifuged (MIKRO 20 Hettich Zentrifugen, Germany) within two hours following collection at 3,500 rpm for 15 minutes and serum was transferred into chilled tubes and immediately stored at -20°C until analysis.

Determination of GI and insulinemic index

Determination of blood glucose concentration

Serum glucose analysis was carried out using the glucose oxidase procedure (Human Glucose liquicolour, complete test kit (Human GmbH) following standard protocol. Two positive controls were assayed daily before each set of serum samples. Inter-assay coefficient of variation (CV) was 0.05% and 0.04% for the respective controls. Each serum sample was analysed in duplicate.

Measurement of serum insulin concentration

Serum insulin concentration was analysed using a solid-phase, enzyme-labelled chemiluminescent immunometric assay on Immulite 1000 automated analyser using standard protocol (Semens Healthcare Diagnostic Products Ltd. USA). Inter-assay CV for the low control was 5.6% and high control was 4.2%. Each serum sample was analysed in duplicate.

***In-vitro* analysis**

Determination of the proximate compositions of the healthy snack

The baked heathy snack was crushed into small pieces and sun-dried over two days until there was no further weight change to the first decimal place. It was then oven dried at 55°C until no further weight change as measured on an analytical balance, which took a further five hours. It was then ground to a fine powder using a mortar and pestle and 0.5 g of this powder was used for analysis. Standard methods were used to determine digestible carbohydrate (Holm *et al.*, 1986), total starch (solubilizing the sample with 2 M KOH) followed by fat (Croon and Guchs, 1980), protein (AOAC, 1984) and dietary fiber (Asp *et al.*, 1983) of the healthy snack. Each sample was analyzed in triplicate.

In vitro starch digestibility of the healthy snack

In vitro starch digestibility of the healthy snack was analyzed using Englyst's method (Englyst and Hudson, 1996). A sample of 100.0 mg was incubated at 37°C for 30 mins in a shaking water bath at 250 rpm with 10 mL of pepsin (Sigma) solution (5.0 g/L pepsin dissolved in 0.01M HCl), 5.0 g/L guar gum (Sigma) and 5 glass balls (d=5mm). The pH value was then adjusted to 5.8 using 0.25 M sodium acetate buffer. A mixture of pancreatin (Sigma) (4.0 g/L) and amyloglucosidase (Sigma) (3.0 mL) was then added and incubated for 20 mins. 0.2 mL of the reaction mixture was taken and placed in 1.8 mL ethanol (99.5 %) to inactivate the enzyme. This mixture was then centrifuged at 4696 g for 20 mins and 10 µL of supernatant was taken to determine the glucose concentration (G20) using the glucose oxidase method, to yield RDS values. All samples were analyzed in triplicate.

The same procedure was repeated at 30, 60, 90 and 120 mins of incubation and the glucose concentration was determined, which yielded SDS values for each food in triplicate. The equations of Englyst and Cummings (Englyst HN and Cummings H,1985) for RDS, SDS and the starch digestion index (SDI) used are as follows: RDS = G20*0.9, SDS=(G120-G20)*0.9 and SDI = (RDS/TS)*100.

Predicted glycemic index through starch digestibility of the healthy snack

The starch hydrolyzation using Englyst's (Englyst and Hudson, 1996) method was plotted as glucose concentration against time for 120 minutes for the test food and white bread (standard) in order to calculate the area under the curve in each case. The hydrolysis index (HI) for the calculation of predicted glycemic index was calculated as the ratio between the area under the hydrolysis curve (0 - 120 mins) of the test food and the area under the curve for the standard food (white bread) and expressed as a percentage of total glucose released.

Predicted glycemic index (pGI)

pGI was calculated using the equation, pGI=39.21 + 0.803 (HI) (Odenigbo *et al.*, 2013).

RESULTS

The mean (±SD) proximate compositions of the healthy snack were 12.35 ± 0.77 g/100 g of protein, 15.00 ± 0.36 g/100 g of fat, 3.47 ± 0.31 g/100 g of soluble dietary fiber, 1.8 ± 0.45 g/100 g of insoluble dietary fiber and 61.70 ± 0.48 g/100 g of digestible starch providing 441.8 kcal/100 g of energy (~ 147 kcal/per serving). The macronutrient composition of commercially produced locally available healthy snack and the corresponding percentage contribution to energy is presented in Table 1.

Table 1. Nutrient compositions and % contribution to energy of the health snack

Nutrient	Formulated healthy snack	% Energy contribution	
		Healthy snack	*EASD recommendation
Carbohydrate (g/100g)	61.70	11.80	10 - 20
Protein (g/100g)	12.35	30.55	20 - 35
Fat (g/100g)	15.00	58.27	45 - 65
Dietary fiber (g/100g)	5.27		
Energy (kcal)	441.84		

EASD = European Association for the study of diabetes (https://www.easd.org).

Total starch and its fractions, RDS, SDS and RS of the main ingredients (chickpea, barley, foxtail millet and Olu) that were used to prepare the healthy snack, are presented in Table 2. The mean (±SD) starch fractions of the healthy snack as total starch, and its fractions, RDS, SDS and RS were 64.36 g/100 g, 22.75 ± 0.78 g/100 g, 5.82 ± 0.76 g/100 g, and 2.66 ± 0.5 g/100 g, respectively.

Table 2. Weight of rapidly digestible starch (RDS), slowly digestible starch (SDS), total starch (TS) and resistant starch (RS) present in 100 g of the main ingredients and in the formulated healthy snack

Parameter	**Ingredients in the formulated healthy snack**				**Healthy Snack**
	Chickpea	**Barley**	**Foxtail millet**	**Olu rice**	
RDS(g/100g)	17.53	24.78	13.90	21.24	22.75 ± 0.78
SDS(g/100g)	3.51	2.53	9.69	5.31	5.82 ± 0.76
TS(g/100g)	62.64	72.61	71.44	69.45	64.36
RS(g/100g)	4.541	3.511	4.588	2.80	2.66 ± 0.5

The enzymatic hydrolysis curves for the standard food (white bread) and the healthy snack are depicted in Figure 1. The hydrolysis Index (HI) calculated from the hydrolysis curves and the corresponding pGI was 41.17 and 43.69 respectively. Starch digestion index is a measure of the relative rate of starchdigestion, and it was 34. Starch digestion index, HI and the corresponding pGI of the ingredients are depicted in Table 3.

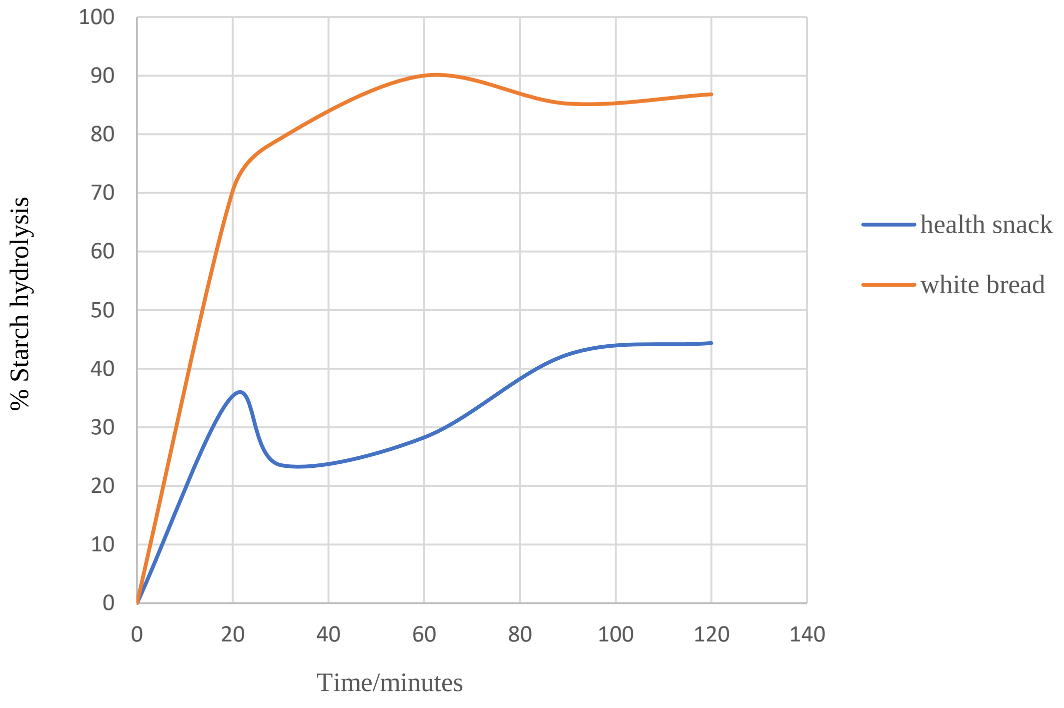

Figure 1. Hydrolysis curves for the standard food and test food

Table 3. Hydrolysis index (HI), predicted glycemic index (pGI) and starch digestion index (SDI), of the main ingredients present in the snack.

	Chickpea	Barley	Foxtail millets	Olu rice
HI	41.99	74.01	43.40	58.45
pGI	23.91	41.49	24.69	32.95
SDI	38.50	21.60	33.00	36.92

The blood glucose and insulin curves for the standard food (glucose) and test food are shown in Figure 2. The glycemic index and the insulinemic index of the healthy snack were 36.5 and 47.79, respectively. Serving size was determined to be 33 g, which provides 147 kcal.

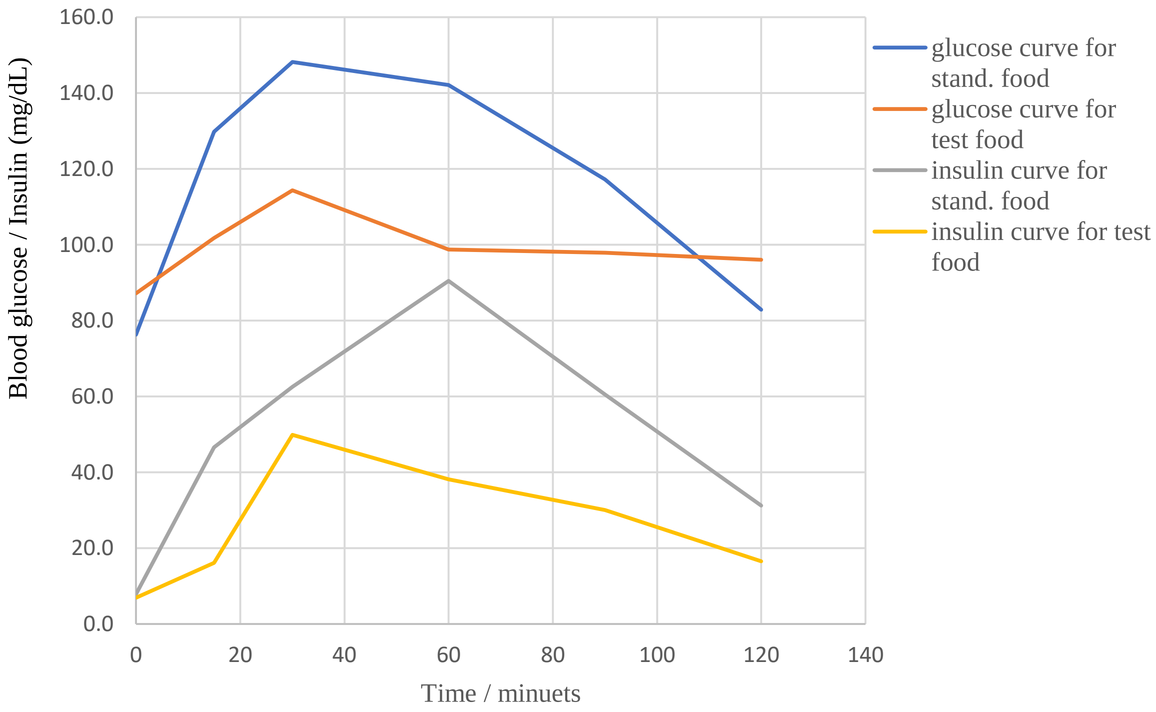

Figure 2. Blood glucose curves and insulin curves for the standard food (glucose) and test food.

DISCUSSION

The contribution to energy from macronutrients, protein, carbohydrate and fat of the formulated healthy snack fell within the recommendations of the European Association for the Study of Diabetes (EASD) (EASD,2004). The percentage contribution from the macronutrients to total energy of the formulated snack compared well with the Nigerian diabetic snacks formulated by Onyechi *et al.*, 2013.

The glycemic index of the healthy snack fell within the low glycemic index range (≤55), as defined by the American Diabetes Association (American Diabetes Association, 2013). The predicted glycemic indices (pGI) of the ingredients varied from 23.91-41.49, whereas the pGI of the formulated snack was 43.69 and the actual glycemic index was 36.5. All these values fell within the low GI category of foods. Prolonged or increased postprandial insulinemia has been shown to play a role in the development of insulin resistance and associated disease (Blaak *et al.,* 2012). The insulinemic index of the formulated snack was low. The estimation of the insulinemic index of foods is both theoretically and practically significant as it will be important in the treatment of DM. The formulated healthy snack reported a lower GI, to that of snacks available in the local market.

Soluble dietary fiber is recognized as one of the major factors that can significantly decrease the blood sugar response and thus promotes a lower glycemic index (Hallfrisch and Behall, 2000). This effect is due to the viscous nature of soluble fiber which is capable of thickening the food in the digestive tract thereby slowing down the action of digestive enzymes on starch. The fiber content of the formulated healthy snack contains a higher soluble fiber to insoluble fiber ratio and is possibly a one reason for its lower glycemic index.

Although the *in-vivo* digestion process is considered a better method, compared to *in-vitro*, the *in-vivo* method is very complex and exact replications are not possible. However, studies done by Holm *et al*, 1988 and Yoon *et al*, 1983 have shown a strong correlation between *in-vivo* and *in-vitro* starch digestibility. The RDS is the amount of starch hydrolyzed within the first 20 mins of incubation with digestive enzymes. It is rapidly hydrolyzed, therefore results in a quick rise in blood glucose and insulin response (Ells *et al*, 2005). The SDS is the amount of starch hydrolyzed between 20-120 minutes of incubation, it is slowly hydrolyzed by digestive enzymes and is absorbed slowly, therefore results in a slow and steady rise in blood glucose. In this study, incubation time was fixed at 30 min to standardize and allow for comparison of the different ingredients and the test food (Englyst and Hudson, 1996). The SDS value for the formulated snack was high (5.82 ± 0.76 g/100g).

In understanding the properties of the formulated snack, the SDI, SDS and RDS of the four main ingredients were also determined. The SDI was found to range between 21.60 to 38.50 for the four ingredients. The SDS of the ingredients were highest for foxtail millet followed by Olu rice, chickpea and barley. Foxtail millet had the highest amount of SDS and the lowest amount of RDS compared to Olu rice, barley and chickpeas. Results for hydrolyzation percentages at 30 min identified that barley (48.97 %) was the most rapidly hydrolyzed ingredient followed by chickpea (24.3%), Olu rice (34.4%) and foxtail millet (22.9%). It is interesting that the formulated healthy snack achieved a hydrolyzation rate similar to the ingredient with the lowest rate, foxtail millet and was 23.57%, which indicates that the SDS fraction is higher than the RDS fraction in the snack. The importance of formulating a food which retains the starch digestibility properties of the ingredients used as demonstrated in this study is paramount, as there is increasing evidence for the link between processing of food and chronic disease.

Differences in the digestibility of starch among species is due to factors such as the source of starch (Ring *et al.,*1988), granular size (Snow and O'Dea 1981) amylose/amylopectin ratio (Hoover and Sosulski, 1985), degree of crystallinity (Hoover and Sosulski, 1985), and the type of crystalline polymorphic sites (Jane *et al.,* 1997). It is known, as demonstrated by Snow & O'Dea (1981) as early as 1981, that reducing particle size increases the surface area which results in a higher starch hydrolysis rate as they demonstrated through grinding rice (both brown and white). Chickpeas, barley, foxtail millet and Olu rice were selected for the formulation of the snack as they have documented benefits in the management of DM.

A study done by Naismith *et al.*, 1991, showed that diabetic rats fed with diets containing barley or wheat exhibited a significantly lower blood glucose concentration, and weight loss. A diet formulated with foxtail millet by Jali *et al.*, 2012 showed that a daily consumption of 80 g of foxtail millet lowered HbA_{1c}, fasting blood glucose and homocystine concentrations and increased the insulin concentration in blood. In another study by Thathola *et al.*, 2011, showed a significant reduction of serum glucose, cholesterol and LDL levels with foxtail millet biscuits. Yang *et al.*, 2007 have shown that dietary chickpeas improved insulin resistance and reversed impaired glucose intolerance in long term high-fat fed animals. These ingredients demonstrate health benefits, some of which can be explained by their starch digestibility properties and some of which have not yet been fully explained. The present study demonstrated that a combination of these ingredients in a healthy snack retains the beneficial properties related to glycemic index and insulinemic index. While these indices have been used predominantly in the management of patients with DM. There is now increasing evidence that healthy individuals are also benefitted with the food items having these properties. It is therefore increasingly important to develop such products retaining the properties of the individual ingredients by low levels of processing as in the current study. A key strength of this study is that it offers a new perspective in formulating healthy snacks. Further, it researched both on the insulinemic index and the GI of the formulated snack. The main limitation of this study is the lack of information on moisture content, ash and total sugars.

CONCLUSIONS

The predicted glycemic indices (pGI) of the ingredients varied from 24.69 - 41.49, whereas the pGI of the formulated snack was 43.69 and the actual glycemic index was 36.5 and fell within the low GI category of foods. A low glycemic index healthy snack, with recommended quantities of protein, carbohydrate and fat and a high quantity of soluble dietary fiber was formulated using the main ingredients Olu rice, foxtail millet, barley, and chickpeas. Further, we effectively formulated a healthy snack which retains a major proportion of the properties of the main ingredients used. A healthy snack with a low glycemic index can be prepared with locally available food items/ingredients ensuring the cultural acceptability of Sri Lankans.

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CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

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Antioxidant Properties of Selected Underutilized Fruit Species of Sri Lanka after Simulated Oral and Gastro-Intestinal Digestion

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ABSTRACT

Background: High consumption of natural antioxidants, particularly phenolic compounds found in fruits and vegetables, makes a significant contribution to plasma antioxidant capacity. The impact of plant phenolics in terms of health benefits is strongly reliant on their level of bioaccessibility and bioavailability.
Objectives: The study was conducted to determine the antioxidative properties and bioaccessibility in six underutilized fruit species, namely (*Phyllanthus emblica*, *Elaeocarpus sirratus*, *Cynometra cauliflora, Aegle marmelos, Limonia acidissima* and *Flacoutia indica*).
Materials & Methods: The total phenolic content (TPC) of fruit samples was determined after in-vitro simulated oral and gastro-intestinal digestion. The total phenolic content of dialysate and retentates were determined using the Folin-Ciocalteu's test. 2, 2-diphenyl-1-pycrylehydrazyl (DPPH) and the total antioxidant activity assay (2,2'azinobis3-ethylbenzothiazoline-6-sulphonic acid (ABTS)) were used to assess radical scavenging activity (RSA) and total antioxidant activity (TAA), respectively.
Results: The highest TPC (110.33 mg of gallic acid equivalents (GAE)/g on dry weight (DW) basis), the highest DPPH radical scavenging activity as measured by IC_{50} value (0.09 mg of dried fruit/mL), and the highest percentage of TAA (90%) were exhibited by *P. emblica* while the *C. cauliflora* recorded the lowest. Among the tested fruit species, P. *emblica* also had maximum bioaccessibility of total polyphenols (83.66 %) and *C. cauliflora* had the lowest (40.16%).
Conclusions: *Phylanthus emblica* had the highest TAA and RSA of the tested fruit species while lowest was recorded in *C. cauliflora.* The TPC, TAA and RSA of all fruit species increased after enzymatic digestion. Further *in vitro* and *in vivo* studies should be conducted to assess the bioaccessibility and bioavailability of individual phenolic compounds.

INTRODUCTION

Epidemiological studies have reported a link between high intake of fruits and vegetables and a reduction in diseases caused by oxidative stress, which is specifically linked to the antioxidant property of phytochemicals (Souza *et al*., 2015). High consumption of natural antioxidants, particularly phenolic compounds found in fruits and vegetables, makes a significant contribution to plasma antioxidant capacity, and these constituents have been shown to reduce the damage caused by oxidative stress (Lie-Fen *et al*., 2005). However, the impact of plant phenolics in terms of health benefits is strongly reliant on their level of bioaccessibility and bioavailability (Shahidi and Peng, 2018). Thus, many *in vivo* and *in vitro* models are used to investigate the bioaccessibility and bioavailability of phenolics. *In vitro* digestion models are widely used because they are less expensive, easier to operate, have a higher efficiency, and are more reproducible than *in vivo* models (Minekus *et al*., 2014). The static simulated digestion model is a simple and widely used *in vitro* method for screening the bioaccessibility of polyphenolic compounds (Carbonell-Capella *et al*., 2014).

The ability to determine the biological activity of dietary components requires knowledge of absorption in the digestive system (Shahidi and Peng, 2018). The bioaccessibility refers to the portion of bioactive compounds absorbed from the intestine that are released from the food matrix after digestion (Shahidi and Peng, 2018), whereas the bioavailable fraction is the fraction of parent compound found in the systemic circulation or at the target site after absorption (Ştefănescu *et al*., 2019). The bioaccessibility was the primary factor limiting the bioavailability, making it important to assess (Campos-Vega *et al*., 2015).

Sri Lanka is a tropical country with a diverse plant population, including over 230 fruit species from 57 plant families (Pushpakumara *et al*., 2007). Aside from commonly consumed fruit crops such as banana, pineapple, papaya, mango, avocado, and rambutan, there are a myriad of underutilized fruit species that grow naturally in diverse regions around Sri Lanka and contribute to traditional recipes (Rajapaksha, 2007).

Extensive research has been done recently on the antioxidant qualities of underutilized fruit species. Silva and Sirasa (2018) evaluated the antioxidant capacities of 18 underused fruit species with those of fruit species that are marketed commonly (mango and banana). The findings showed that some rarely consumed fruit species contained more antioxidants than more widely consumed fruits. The antioxidant efficacies of 21 underutilized Sri Lankan fruit species were examined by Mallawaarachchi *et al*. in 2021, suggesting their potential as natural antioxidant sources. Despite the *in vitro* antioxidant properties of underutilized fruits, reports on the antioxidant properties of bioaccessible phenolics derived from them are scarce. In this study, the antioxidant properties of bioaccessible phenolics of chosen underutilized fruit species were assessed after simulated oral and gastro-intestinal digestion.

MATERIALS & METHODS

Fruit Samples

Healthy and ripe fruits of six fruit species namely, *Phyllanthus emblica* L., *Elaeocarpus sirratus* Linn, *Cynometra cauliflora* Linn., *Aegle marmelos* L. Correa, *Limonia acidissima* L. and *Flacoutia indica* (Burm. f.) (Plate 1) were collected from home gardens in the upcountry intermediate zone (IU3) of Sri Lanka during the peak production period of 2018. Cold transport was used to transport the collected fruit samples to the analytical laboratory at the Regional Agriculture Research and Development Centre in Bandarawela. They were then inspected for defects, washed, and drained at room temperature before being authenticated (Rajapaksha, 1998) and photographed. The color of the fruits were recorded, and a hundred grams of edible portions of the fruits from each fruit species were taken and homogenized. The *in vitro* digestion study employed five grams of each homogenate in triplicate.

Chemicals and reagents

The analytical grades of gallic acid, methanol, Folin-Ciocalteu's phenol reagent, sodium carbonate, 2,2-diphenyl-1-picrylhydrazyl hydrate (DPPH), 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) di-ammonium salt (ABTS), 2,2-Azobis (2-amidinopropane) di-hydrochloride (AAPH), hydro chloric acid (99%), magnesium chloride hexa-hydrate, potassium chloride, potassium di-hydrate phosphate, sodium bi-carbonate, ammonium carbonate, calcium chloride di-hydrate, sodium hydroxide, piperazine NN'-bis (2-ethane-sulfonic acid) (PIPES), α-amylase from human saliva (300-1500 units/mg, Type XIII-A, lyophilized powder), pancreatin from porcine pancreas, pepsin from porcine gastric mucosa ≥500 units/mg, porcine bile extract were purchased from Sigma, USA.

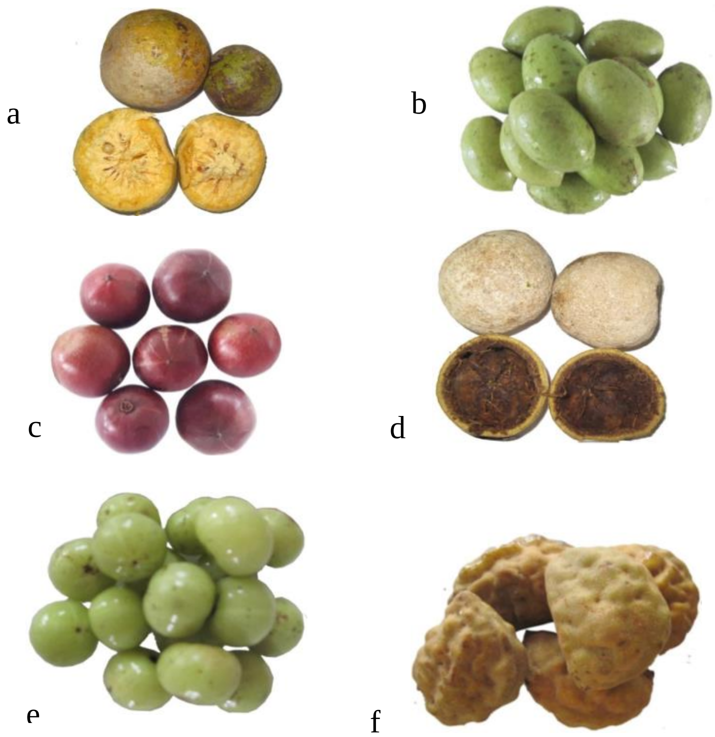


Plate 1. Selected fruit species.
(a-*Aegle marmelos*, b- *Elaeocarpus serratus*, c- *Flacourtia indica*, d- *Limonia acidissima*, e- *Phyllanthus embilica*, f- *Cynometra cauliflora*)

Preparation of digestion fluids

Table 1 summarizes the ionic solution proportions used to prepare simulated salivary fluid (SSF), simulated gastric fluid (SGF), and simulated intestinal fluid (SIF) (Minekus et al., 2014). To obtain final ionic concentrations and to adjust appropriate pH in corresponding digestion fluids, volumed up with distilled water and 1 M NaOH and 6 M HCl were used, respectively. Salivary α-amylase (1500 units/mL), porcine pepsin (2000 units/mL) and porcine pancreatin (800 units/mL) solution were prepared separately in electrolyte solutions SSF, SGF, and SIF (Minekus et al., 2014). In 250 mL of SIF, three grams of porcine bile extract were dissolved (Akillioglu and Karakaya, 2010).

Table 1. Concentrations and compositions of ionic solutions (in 500 mL)

Constituent	Concentration of ionic (stock) solutions (mol/L)	SSF at pH 7	SGF at pH 3	SIF at pH 7
		Stock volume (mL)	Stock volume (mL)	Stock volume (mL)
KH_2PO_4	0.5	3.70	0.90	0.80
KCl	0.5	15.10	6.90	6.80
$NaHCO_3$	1.0	6.80	12.50	42.50
$(NH_4)_2 CO_3$	0.5	0.06	0.50	-
NaCl	2.0	-	-	9.60
$MgCl_2 6H_2O$	0.15	0.50	0.40	1.1
$CaCl_2 2H_2O$	0.3	25 µL†	5 µL†	40 µL†

†Added to the sample at the beginning of digestion
SSF = Simulated salivary fluid, SGF= Simulated gastric fluid, SIF = Simulated intestinal fluid

Simulated digestion

Figure 1 depicts the detailed procedure. The simulated digestion was carried out using combined methods described by Akillioglu and Karakaya (2010) and Minekus *et al*. (2014), with some modifications. Samples were prepared using enzymes (experimental group) and without enzymes (control group). Then, the digestion was carried out in 100 mL polystyrene tubes dipped in a shaking water bath at 37 °C. Following oral and gastric digestion, dialysis tubes (typical molecular cut off point of 14 000) with PIPE buffer were dipped in each polystyrene tube to proceed to the intestinal digestion phase. The pH of the digestion media was adjusted accordingly in each phase. Following incubation, polystyrene tubes containing samples and dialysis tubing were immersed in a water bath at 90 °C for 10 minutes (Hollebeeck *et al*., 2013). The dialysis bag was then removed and washed with distilled water. Supernatants of retentate and dialysate were collected after centrifugation to be used in the respective assays.

Determination of total phenolic content

The total phenol content was determined using Folin-Ciocalteu colorimetric assay (Yu *et al*., 2002). In brief, 20 µL of sample (supernatants of dialysate/retentate) was vortexed with 100 µL and 1.58 mL of 2 N Folin-Ciocalteu's reagent and distilled water, respectively, and allowed to stand at room temperature for 8 min, before adding 300 µL of 0.7 M sodium carbonate and incubating for 30 min at room temperature, absorbance was measured at 765 nm by using Helios Omega–UV–VIS spectrophotometer. The samples were examined in triplicate.

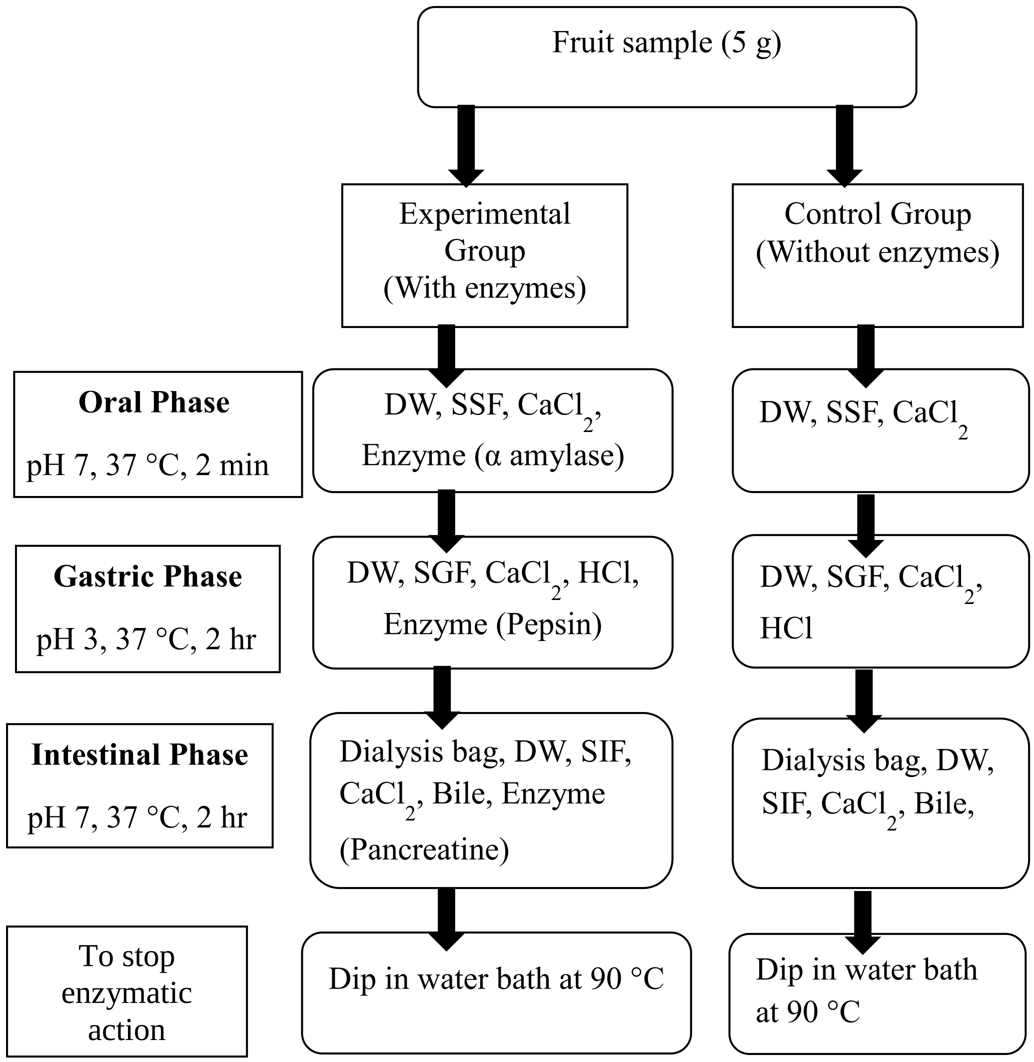


Figure 1. Schematic diagram depicting simulated digestion steps
(DW= Distilled water, SSF= Simulated salivary fluid, SGF= Simulated gastric fluid, SIF= Simulated intestinal fluid)

The TPC was calculated using the gallic acid standard curve (y= 0.0007x, R^2=0.9999) and expressed in milligrams of gallic acid equivalents (GAE) per gram of dried fruit.

Determination of DPPH (2,2-diphenyl-1-pycrylehydrazyl) radical scavenging activity

The DPPH radical scavenging assay (Su *et al*., 2007) was used to assess the radical scavenging activity (RSA) of the dialysates and retentates. For that, 0.02 – 0.20 mL of each dialysate and retentate were used to prepare six different concentrations, and methanol was added to obtain the final 2.0 mL of reaction medium with 1.8 mL of 0.1M methanolic DPPH solution. The results were expressed as IC_{50} values, which denote the concentration of extract required to scavenge 50% of the DPPH radical in the reaction medium, as determined by the percentage of color disappearance of the DPPH solution vs. concentration plot.

Determination of total antioxidant activity

Total antioxidant activity (TAA) assay was used to determine the TAA as described by

Zhou and Yu (2004). To perform the TAA assay 1.96 mL of stock (2.5 mM ABTS in PBS buffer at pH 7.4 and 2 mM AAPH in PBS buffer at pH 7.4 in 1:1 ratio) was mixed with 0.04 mL of samples (retentate and dialysate), and absorbance was measured at 734 nm on the 1st, 3rd and 6th minute. Over a six-minute period, the results were expressed as a percentage inhibition of ABTS radical cation in terms of RSA. The following equation was used to compute the RSA.

$$\text{RSA\%} = \{1 - (A_{\text{sample}}/A_{\text{control}})\} * 100$$

A_{sample}= Absorbance of the sample and
A_{control} = Absorbance of the control

Determination of bioaccessibility of phenolic compounds

The bioaccessibility is the proportion of bioactive compounds that are liberated from the food matrix during digestion and absorbed from the intestine (Shahidi and Peng, 2018) and calculated as follows.

$$\text{Bioaccessibility (\%)} = \frac{\text{TPC in dialysate}}{\text{TPC in dialysate} + \text{TPC in retentate}} \times 100$$

TPC = Total phenolic content

Statistical analysis

SAS 9.1 statistical software was used to analyze quantitative data on bioaccessible total phenolic compounds, DPPH radical scavenging activity, and total antioxidant activity of retentate and dialysate. Analysis of variance and least significant difference tests were used to identify mean differences at 5% probability.

RESULTS

Bioaccessibility, total phenolic content and antioxidant activity of dialysates and retentates

The bioaccessibility of phenolic compounds, total phenolic content (TPC, Table 2), DPPH radical scavenging activity (IC_{50}, Figure 2) and total antioxidant activity (TAA, Figure 3) of the supernatants of dialysate and retentate obtained after oral and gastro-intestinal digestion were all determined. After oral and gastro-intestinal digestion, the bioaccessibility of total phenols in selected fruit species ranged from 40% in *C. cauliflora* to 84% in *P. emblica* (Table 2), *A. marmelos* had the second highest bioaccessibility, while the percentage absorbed by *F. indica* and *L. acidissima* was not significant. After gastro-intestinal digestion, nearly 50% of total phenols (TP) of *E. serratus* were bioaccessible. The dialysate and retentate obtained after enzymatic digestion of *P. emblica*, possessed the highest sum of total phenols while *C. cauliflora* possessed the lowest. The sums of the control group's TP values ranged from 5.69 mg GAE/g dried fruit in *C. cauliflora* to 106.54 mg GAE/g of dried fruit in *P. emblica*. Meanwhile, the TPC of dialysate and retentate obtained from the control group of all fruit species that were performed without enzymatic digestion were significantly lower than those obtained from the experimental group of each fruit species.

DPPH radical scavenging activity of dialysates and retentates

Figure 2 depicts the radical scavenging activity (RSA) of each dialysate and retentate. Lower IC_{50} values indicate the higher RSA, thus the dialysates of experimental group had the lowest IC_{50} values among four groups in each fruit species, indicating that RSA was increased after enzymatic digestion. Zhou *et al*. (2016) discovered the same results in the dialysate obtained after *in vitro* gastrointestinal digestion of elderberry. *P. emblica* possessed the lowest IC_{50} value, 0.09 mg of dried fruit/mL in both experimental and control dialysates, and 0.10 and 0.16 mg of dried fruit/mL in experimental and control retentates, respectively, denoting the highest RSA and not being significantly different at $p < 0.05$ (Figure 2). *F. indica* had the highest IC_{50} values for all four groups exhibiting lowest RSA (3.94 and 4.95 mg of dried fruit/mL for the dialysates of the experimental and control groups, 4.21 and 5.06 mg of dried fruit/mL for the retentates of the experimental and control groups, respectively) (Figure 2). The second highest IC_{50} values for all four groups were obtained by *L. acidissima*.

While *E. serratus* had the second lowest IC_{50} with 0.44 mg of dried fruit/mL in experimental group dialysate (Figure 2). *C. cauliflora*, which had the lowest bioaccessibility, had significantly lower IC_{50} values than *A. marmelos*, *F. indica* and *L. acidissima* for the dialysate of experimental group.

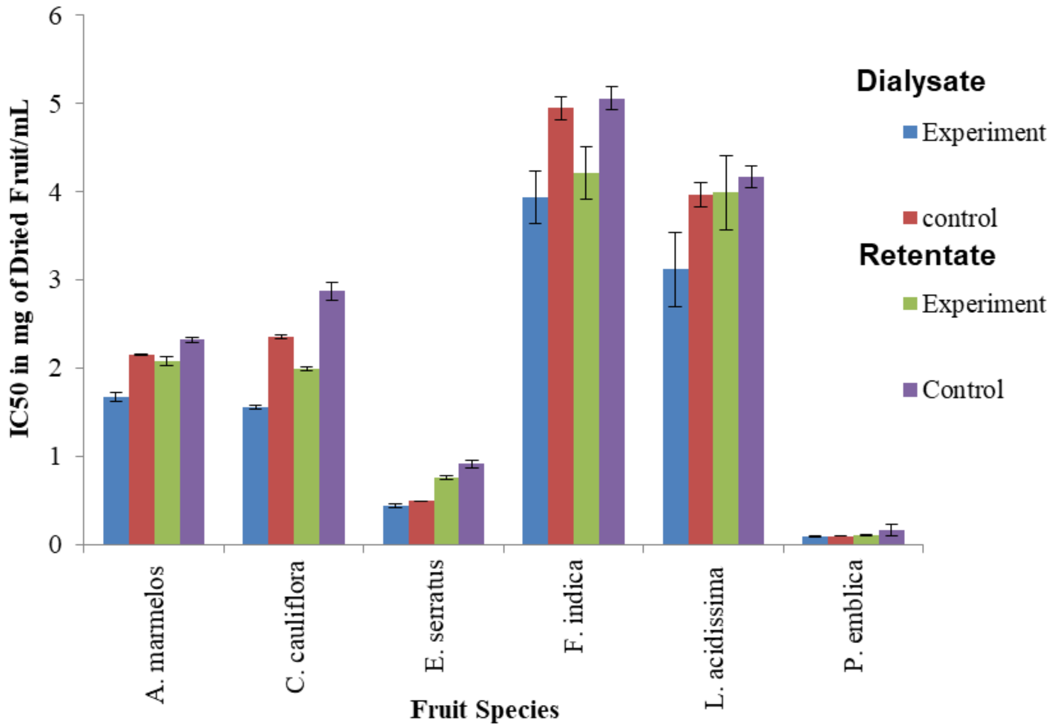
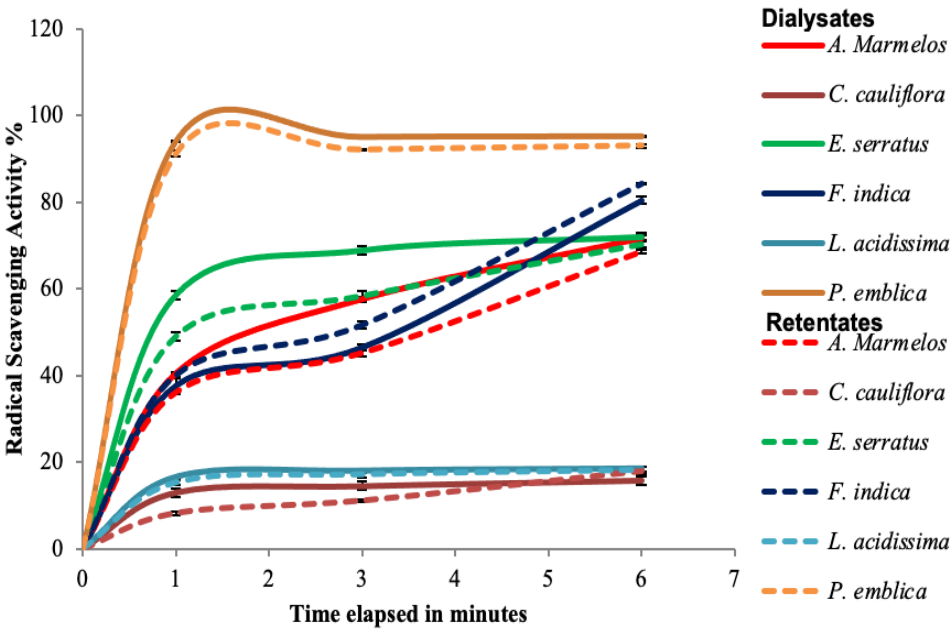


Figure 2. IC50 values in milligrams of dried fruit/mL of dialysates and retentates of experimental and control groups

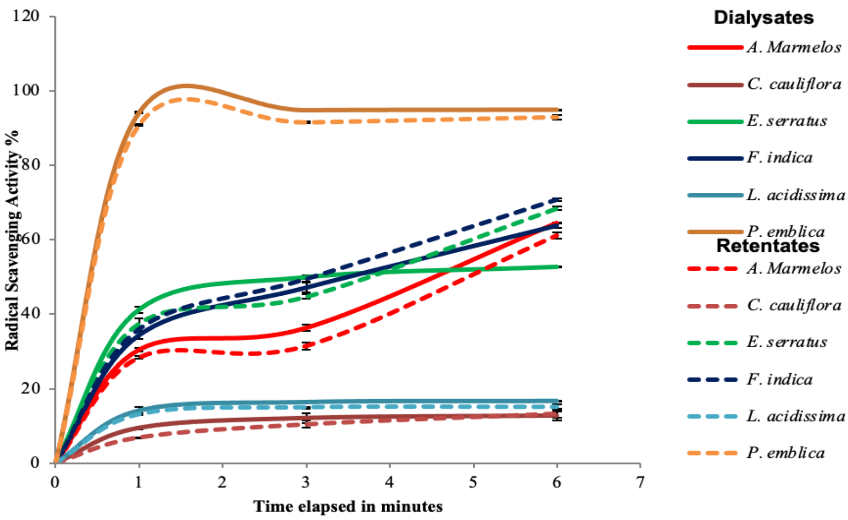
Total antioxidant activity of dialysates and retentates

The ABTS assay was used to assess total antioxidant activity (TAA) based on RSA, which indicates the ability of dialysates and retentates to reduce the color of deep blue green ABTS radical cation stock solution. The TAA as RSA of each fruit species is depicted in Figure 3 over a six-minute reaction time. The dialysate and retentate of the experimental group of *P. emblica* demonstrated the highest TAA, achieving more than 90% RSA within the first minute and eventually reaching 95% and 93% RSA, respectively (Figure 3a).

The second highest RSA was found in *F. indica* at sixth min, in which the retentate (84.4%) had a significantly higher RSA than the dialysate (80.5%). After six minutes, the RSA of *A. marmelos* (71.8%) and *E. serratus* (71.9%) dialysates were not significant. Although *A. marmelos* exhibited approximately 40% RSA, *E. serratus* exhibits 58% RSA within the first minute. The RSA values of *C. cauliflora* and *L. acidissima* dialysates and retentates were not-significant and had the lowest RSA of any fruit species tested. Furthermore, the reaction of *F. indica* in both dialysate and retentate with ABTS cation radicals were increased rapidly after the 3rd minute, whereas other fruit species, with the exception of *A. marmelos*, remained constant (Figure 3a). Figure 3b depicts the RSA of undigested (control) groups, revealed significantly lower RSA values for dialysates and retentates than in experimental group for all fruit species except *P. emblica*.



3a. Radical scavenging activity of dialysates and retentates of fruit pulp after oral and gastrointestinal digestion



3b. Radical scavenging activity of dialysates and retentates of undigested fruit pulp

Figure 3. Radical scavenging activity of dialysates and retentates

Table 2. Total phenolic content of dialysates and retentates and bioaccessibility of total phenolics of selected fruit species

Fruit Species	*Sinhala* Name	Bioaccessibility of total phenolics (%) of experimental group	†TPC (mg GAE/g of DW) ‡					
			Dialysate		Retentate		Total	
			Experimental group	Control	Experimental group	Control	Experimental group	Control
A. marmelos	*Beli*	74.08 ± 2.36^{b}	28.69 ± 0.32^{bA}	18.62 ± 0.02^{bB}	10.04 ± 0.41^{bC}	4.84 ± 0.16^{bD}	38.73 ± 2.49^{bE}	23.46 ± 1.59^{bF}
C. cauliflora	*Nami-nam*	40.16 ± 4.58^{e}	4.11 ± 0.13^{dA}	3.17 ± 0.04^{fB}	6.12 ± 0.24^{cC}	2.52 ± 0.43^{dD}	10.23 ± 1.07^{eE}	5.69 ± 0.64^{eF}
E. serratus	*Weralu*	49.25 ± 1.09^{d}	6.25 ± 0.96^{cdA}	4.61 ± 0.08^{eB}	6.44 ± 0.87^{cC}	3.98 ± 0.71^{cD}	12.69 ± 0.98^{dE}	8.59 ± 0.47^{dF}
F. indica	*Uguressa*	64.65 ± 2.79^{c}	8.78± 0.12^{cA}	6.72 ± 0.01^{dB}	4.80 ± 0.08^{dC}	2.56 ± 0.29^{dD}	13.58 ± 0.76^{cdE}	9.28 ± 0.81^{cdF}
L. acidissima	*Diwul*	60.21 ± 3.02^{c}	8.91 ± 0.09^{cA}	7.51 ± 0.09^{cB}	5.89 ± 0.17^{cdC}	2.39 ± 0.14^{dD}	14.80 ± 1.03^{cE}	9.90 ± 0.94^{cF}
P. emblica	*Nelli*	83.66 ± 2.65^{a}	110.33 ±1.79^{aA}	92.30 ± 1.28^{aB}	21.55 ± 1.26^{aC}	14.24 ± 0.93^{aD}	131.88 ± 4.21^{aE}	106.54 ±2.54^{aF}

†Values with different lower-case letters in each column are significantly different at $p < 0.05$
‡ Values with different upper-case letters in each row of each variable are significantly different at $p < 0.05$
Data are presented as Mean ± Standard error, GAE = Gallic acid equivalents. DW = Dry weight basis, TPC = Total phenolic content

DISCUSSION

Bioaccessibility and total phenolic content of dialysates and retentates

Semi-permeable cellulose membranes (dialysis tubes) were used to simulate the intestine's gut epithelial cell layer and to allow for the free diffusion of dietary phenolics. The cut-off molecular weight of dialysis membrane was the factor that determines the penetration. Phenolics with a molecular weight greater than the cut-off point (14 000) remain in the digestive part (retentate), whereas low molecular weight compounds migrate into the dialysate. To achieve the same *in-vivo* ionic concentration, electrolyte stock solutions and digestion fluids were prepared (Minekus *et al*., 2014). After the digestion process, the polystyrene tubes with dialysis bags were dipped in a water bath at 90 °C for 10 minutes to stop further enzymatic reactions (Hollebeeck *et al*., 2013).

The total phenol content (TPC) of dialysate and retentate from the experimental group of each fruit species were considerably higher than those from the control group of all fruit species, which did not undergo enzymatic digestion. This increase in TPC in the experimental group could be attributed to the release of bound phenolics from macromolecules such as protein and carbohydrates during enzymatic digestion. Akillioglu and Karakaya (2010) obtained the same results in common and pinto beans after *in-vitro* digestion.

The TPC of water extracts of ripe fruits before digestion were 21.46, 4.59, 2.19, 14.35, 6.25, and 103.75 mg GAE/g DW in *A. marmelos*, *C. cauliflora*, *E. serratus*, *F. indica*, *L. acidissima* and *P. emblica*, respectively (Mallawaarachchi *et al*., 2021), which were lower than the values obtained after *in-vitro* digestion. Based on those findings of the previous study of the authors, the amount of TP in fruit species increased after *in-vitro* digestion by 80.5% in *A. marmelos*, 122.9% in *C. cauliflora*, 479.5% in *E. serratus*, 136.8% in *L. acidissima* and 27% in *P. emblica* with *F. indica* exhibiting the same level of TP in both raw and digested sections. This could be explained by the extraction solvents' limited ability to extract polyphenolic compounds from the food matrix, as well as pH changes during digestion and the action of digestive enzymes, which may facilitate polyphenol release.

Antioxidant activity of dialysates and retentates

DPPH radical scavenging activity of dialysates and retentates

The radical scavenging activity of dialysates after enzymatic digestion was significantly greater than that of the undigested part (control) (Figure 2). This could be related to the release of bound phenolics from macromolecules, which enhances their solubility, as well as the hydrolysis of conjugate polyphenols as a result of enzymatic activity in the oral, gastric, and intestinal phases, as well as the effect of low pH in the gastric phase.

Total antioxidant activity of dialysates and retentates

Previous research has found that the fruits of *P. emblica* possess a high concentration of vitamin C (523 mg/100 g) (Mallawaarachchi *et al*., 2021). If the composition of vitamin C in the food matrix is high, the bioaccessibility of vitamin C is high (Brandon *et al*., 2014), which contributes between 47% and 70% of the fruit's antioxidant activity (Charoenteeraboon *et al*., 2010). Thus, it may account for its higher TAA. The fact that the retentate of *F. indica* at sixth minute had a much higher RSA than the dialysate may be related to the presence of polyphenolic chemicals that are larger than the molecular cut-off points of the dialysis tubing. Although the RSA of *A. marmelos* and *E. serratus* dialysates were not significant after six minutes, *A. marmelos* had a lower RSA than *E. serratus* within the first minute, indicating that antioxidant compounds in *E. serratus* react with ABTS cation radicals more quickly than antioxidant compounds in *A. marmelos*.

Polyphenol absorption and metabolism are influenced by physicochemical properties such as solubility, molecular weight, and degree of polymerization and conjugation. Both free (aglycones) and conjugated (glycosides) forms of polyphenols are found in dietary matrix, with the former being quickly absorbed from the small intestine and the latter requiring enzymatic hydrolysis to be absorbed (Ştefănescu *et al*., 2019). As a result, the undigested portion of this experiment had lower TP, RSA and TAA values than the digested group. The presence of high tannin content was attributed to high antioxidant efficacy of *P. emblica* (Charoenteeraboon *et al*., 2010). Tannins have a strong affinity for proteins and dietary fiber (Campos-Vega *et al*., 2015), and the action of pepsin in the gastric phase causes these protein-bound portions to be released, increasing antioxidant activity and absorption. This could be the reason for the higher TAA of dialysate and retentate of *P. emblica*. Campos-Vega *et al*. (2015) discovered that tannin boosts antioxidant activity in the absorbed fraction during *in-vitro* simulated digestion of coffee.

Phenols with a high degree of polymerization are fermented and degraded by colonic bacteria or excreted, whereas phenolics with a low degree of polymerization are easily absorbed in the stomach and small intestine (Shaidi and Peng, 2018). As a result, after gastrointestinal digestion, food containing heavily polymerized phenols may have low bioaccessibility. After gastric digestion of apple, 65 percent of phenolics and flavonoids were released, and the antioxidant capacity of dialysable antioxidant was 57% lower than in fresh apples (Bouayed *et al*., 2011); this suggested that some polyphenols bound to macromolecules are non-dialysable, and some aglycones remained in the digesta. The bioavailability and bioaccessibility of each phenolic differed; gallic acid, catechin, flavanone, and quercetin glucosides are well-absorbed, whereas proanthocyanidins and anthocyanins are poorly absorbed (Manach *et al*., 2005). As a result, fruit extracts with high anthocyanin contents may not be more bioaccessible.

CONCLUSIONS

Phylanthus emblica had the highest bioaccessibility of TPC among the selected fruit species (83.66%), followed by *A. marmelos* > *F. indica* = *L.* acidissima > *E. serratus* > *C. cauliflora*. After simulated oral and gastrointestinal digestion, antioxidant efficacy increased in all fruit species. *Phylanthus emblica* had the highest TAA and RSA of the tested fruit species while lowest was recorded in *C. cauliflora*. Further *in vitro* and *in vivo* studies should be conducted to assess the bioaccessibility and bioavailability of individual phenolic compounds.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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Effectiveness of Texture Modified Diets on Dysphagia in Older adults: A Systematic Review

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ABSTRACT

Dysphagia is common among older people and is associated with an increased risk of aspiration pneumonia, dehydration, and malnutrition. Treatment options are limited, and the use of texture-modified diets is a widespread clinical practice in geriatric care. This systematic review aimed at evaluating the evidence available using keyword searches by using recognized electronic databases from 2011 to 2021. Studies were evaluated for their acceptability, then reviewed with data extracted, and grouped by types of outcome measures. A total of 136 publications were identified, and only 10 studies met the inclusion criteria. There were no publications examining the effectiveness of texture-modified diets for older adults (≥60 years) exclusively with dysphagia. However, many studies which had included subjects with dysphagia and texture-modified diets in managing aspiration and providing nutrition and hydration in settings like residential aged-care facilities and hospitals were reviewed in this paper. This review identified the gaps in the area and showed the strong grounds for the need of clinical trials to guide the best practices.

INTRODUCTION

The percentage of the older adult population is growing fast, and this expands the average life span of people. However, many older adults suffer degenerative diseases and nutrition problems that eventually lead to negative health consequences. Data pertaining to world population aging suggests that by the year 2050 one fifth of the population of the developed world will be over the age of sixty years and for the first time in history there will be more older adults than young (World population Ageing, 2001). Dysphagia is classified into three main categories: oral, esophageal, and pharyngeal (Thiyagalingam *et al,* 2021). Swallowing disorders can impair the entering of bolus, liquid, or saliva to the larynx. Dysphagia is caused by a neurological or anatomical disorder that interferes with sufficient fluid and food intake (Copeman & Hyland, 2014). Dysphagia affects the safety and effectiveness of an individual's swallowing function. Safety during swallowing typically refers to the degree of risk of aspiration or entry of food and liquids into the airways below the true vocal cords. Efficacy refers to each patient's efficiency and speed during swallowing food and liquids. Over the past decade, there has been a rising awareness that dysphagia should be recognized as a geriatric syndrome (Payne & Morley, 2017) because, it has a considerable impact on the efficiency and safety of swallowing function in older adults (Baijens, 2016).

Early recognition and proper management of dysphagia are important steps in geriatric care. Symptoms associated with dysphagia in older adults are often overlooked by the patients themselves. Various countries all over the world have documented guidelines for formulatiing diets for patients with dysphagia. However, neither of these guidelines are based on systematic reviews to summarize all the information related to the effect of dysphagia on nutritional status and the prevention of aspiration in older adults. Therefore, this systematic review aims to summarize the evidence from the literature about the effectiveness of texture-modified diets for older adults (≥60 years) suffering from dysphagia with specific relevance to the maintenance of nutrition and hydration status and for the prevention of aspiration.

MATERIALS & METHODS

The PICO (populations, interventions, comparators, outcomes) method was used as the approach to identify studies that met inclusion and exclusion criteria (National Collaborating Centre for Methods and Tools, 2014). The population of interest was older adults (≥60 years) with the diagnosis of swallowing disorders, especially dysphagia. Interventions included only clinical-based therapies using texture modified diets (TMD). The studies examined showed the effect of TMD on at least one clinically relevant outcome.

Search strategy

The electronic bibliographic databases used for data extraction were PubMed / Medline, Elsevier, Google Scholar, ResearchGate, Hindawi, Sage pub, ScienceDirect, and SpringerLink. Searches were limited to articles published from 2011 to 2021. All titles and abstracts of each of the searches were reviewed and then the relevant articles were obtained for review. The search terms used were "Dysphagia in older adults", "Swallowing difficulty", "Aspiration", "Oral health", "Thickened diets", "Texture modified diet" or "TMD". These expressions were used separately or in different combinations. The keywords were intended to capture terms and concepts known to be used in the dysphagia in older adults, their nutrition, and texture-modified food.

Inclusion and exclusion criteria

Inclusion and exclusion criteria are depicted in Figure 1. Studies that were not published in the English language, studies that did not carry full text, studies without clinical studies and studies done with the participation of adults below sixty years, and studies with duplicates were excluded. Before removing duplicates, the initial search results showed 136 articles. Removal of duplicates resulted in 106 articles. In addition to that, unpublished literature, editorials, review articles, conference proceedings, letters to the editor, case studies, and commentaries were also excluded. Any article that appeared to focus solely on participants who were suffering from swallowing problems for which specific reasons had been identified and not due to age were also excluded. Studies focusing on dysphagia in children were also excluded. All the studies having a clinical trial with the participation of older adults over sixty years (60 - 100 years) suffering from dysphagia secondary to non-progressive neurological conditions were included.

Data extraction

The PRISMA checklist was used for data extraction which included participants sample size, interventions, outcomes, and study design as shown in Table 2. Data of all relevant studies were extracted in a spreadsheet using EXCEL version 2019 software (Microsoft Corporation) by one reviewer. Another reviewer abstracted detail regarding the study design, sample size, interventions, outcomes, duration of treatment and follow-up, settings, and results. The abstracted data was checked for accuracy. Out of 10 studies, there were five randomized control studies and five non-randomized control trials. The risks of selection, performance, attribution, detection, and outcome reporting bias were summarized as overall risk of bias as low, some concerns, or high risk of bias.

Quality assessments

The evaluation for risk of bias was performed (Figure 2 and 3) according to the guidelines suggested by the version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2), the recommended tool to assess the risk of bias in randomized trials (Sterne et al, 2019). The ROBINS-I tool was used to assess risk of bias in the results of non-randomized studies (Sterne et al, 2016). Specifically, each study was reviewed to determine whether there was a potential bias in terms of classification of interventions, participant selection, missing data, and reporting of results.

RESULTS

Study selection

The electronic search identified 136 records potentially eligible for inclusion. Following the manual screening of titles, abstracts, full-texts, clinical studies, English language papers and studies on older people above 60 years, 10 publications were eligible for inclusion. All the publications included were based on the older adult population over 60 years and suffering from dysphagia. Both male and female participants were studied in all the included researches.

Criteria used in the search

The questions addressed in the full-text review are listed in Table 1 and led to a final subset of ten articles selected for qualitative synthesis. The questions were addressed when including a particular study into the systematic review. This step was carried out to make sure the validity of the study when selecting exclusively the relevant articles.

Stimulus characteristics

The various food and liquid stimuli used in the studies selected for the qualitative synthesis are summarized in Table 1. Out of the 10 studies selected for systematic review, 5 studies reported comparative data for swallowing of different textured diets including thin liquid (water like liquids) and extremely thick liquids (pureed, spoon thick or mushy diets).

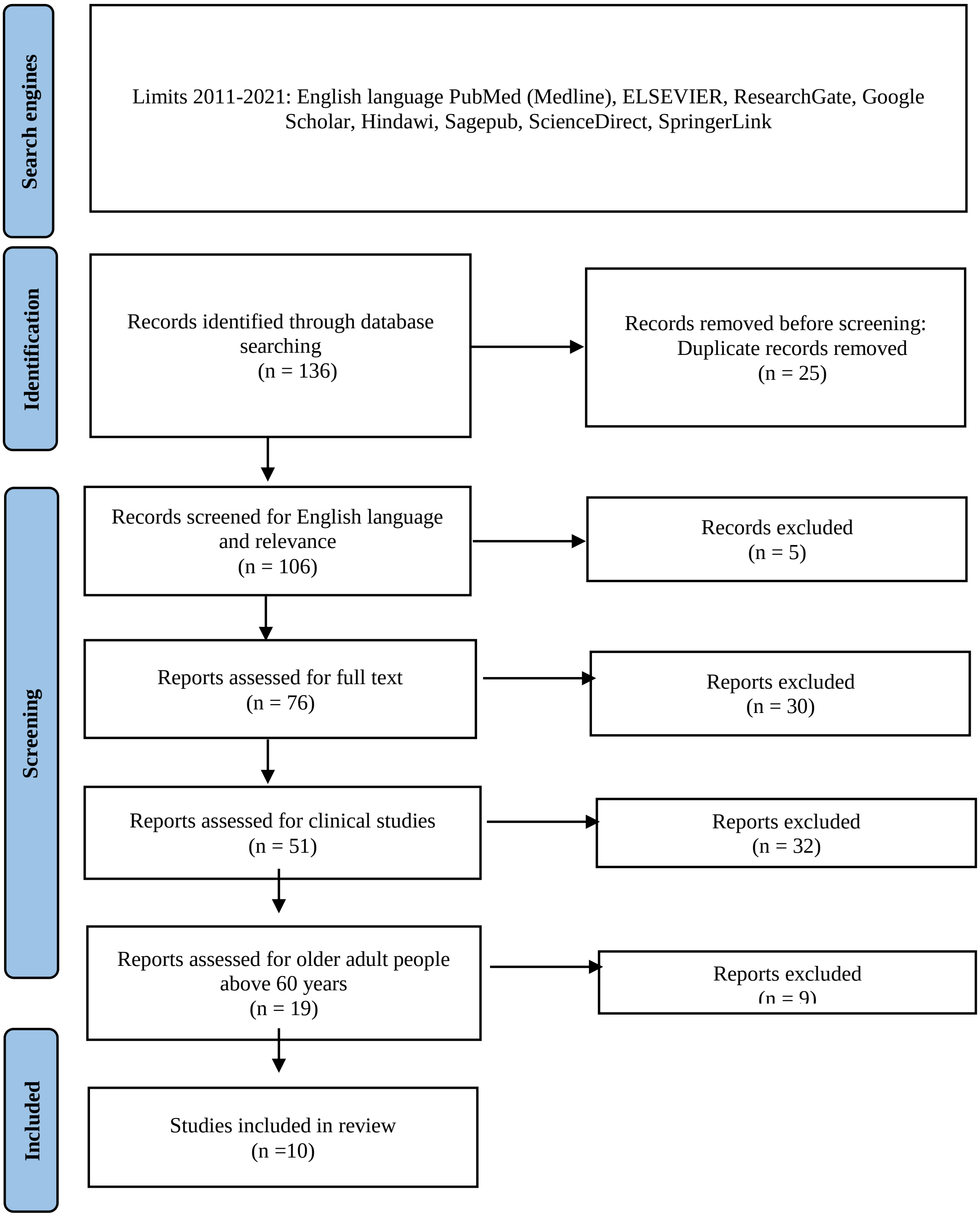

Figure 1. Illustration of experimental design

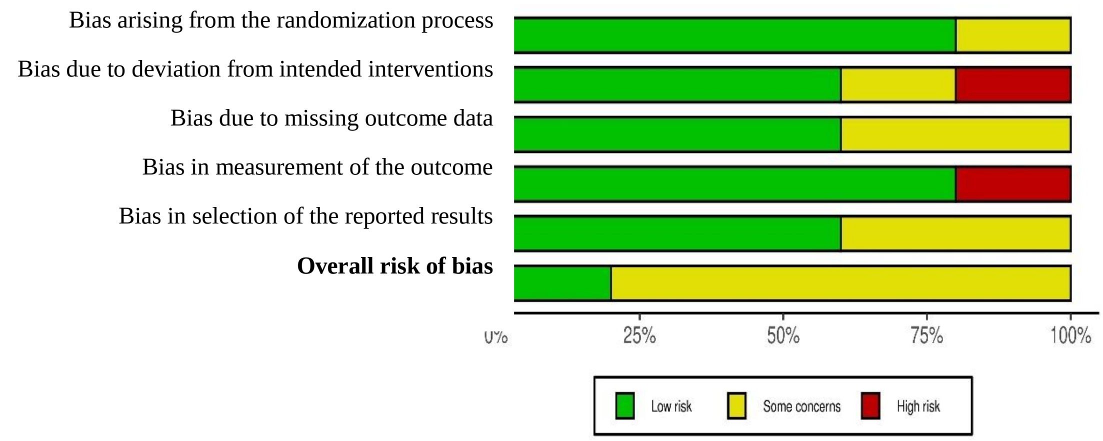

Figure 2. Summary plot on risk of bias assessment in randomized trials

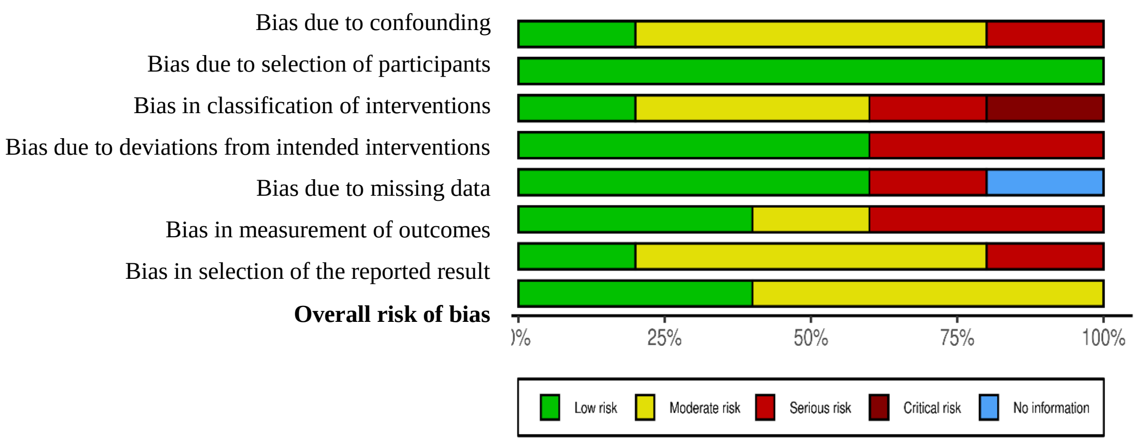

Figure 3. Summary plot on risk of bias assessment in non-randomized trials

Table 1. Questions addressed during the review of relevancy and quality in full-text

Number	Question	Clarifying instructions
1	Is the article is a peer-reviewed manuscript in a journal?	Conference abstracts should be excluded
2	Does the article report swallowing behavior in humans for at least one textures or consistencies?	Articles without original data must be excluded
3	What were the different stimuli tested?	
4	What was the research question?	Please state that clear as possible
5	Is the article published in English language?	
6	Are the participant groups clearly described as above 60 years?	
7	What is the overall conclusion or main finding of this study related to swallowing or oral processing and food/fluid texture?	

Table 2. Characteristics of the studies

Source	Method	Sample size	Patient characteristics & study location	Interventions	Outcome
Oh *et al*,2020	Video fluoroscopic study + Clinical study	30	≥65 yrs. (Korea)	5 bolus types were required to be swallowed by each participant and two skilled physiatrists analyzed the video files. Swallowing supplement development with similar texture and smell as commercialized plain yogurt (spoon thick)	Several patients with Parkinson's disease presented "symptomless dysphagia" upon VFSS evaluation. Swallowing supplement was easier to swallow than a general diet and tolerable to patients with Parkinson's disease.
Li, 2015	A retrospective study	40 (20 from control group)	≥80yrs (China)	Mushy diet for the intervention group and semi-solid food, thick liquid for control group.	Control group, seven patients had aspiration pneumonia. Four patients had aspiration pneumonia in the intervention group.
Torres *et al*, 2019	A randomized control trial	20 (20 controls)	≥65yrs (USA)	Texture modified foods and thickened drinks diet, with nectar or pudding viscosity and controlled bolus volume	The modified consistency and volume diet improved the total energy and protein intake in the intervention group after 12 weeks.
Kyodo *et al*, 2020	randomized cross-over trial	62	≥65yrs (Japan)	Pureed rice with or without a gelling agent	Pureed diets containing a gelling agent may reduce the risk of aspiration pneumonia possibly by decreasing pharyngeal residues in elderly patients with moderate to severe dysphagia.
Taniguchi *et al*, 2014	Multicenter non-blinded prospective cohort study with 1-year follow-up	9528	Residential care patients, >65 years (Japan)	Normal vs minced vs pureed vs parenteral diet	Elderly people who serve pureed diets need to eat more food to meet their nutritional needs than elderly people who provide regular diets. Eating large amounts of food can put a significant physiological burden on them.

Table 2. Cont.

Source	**Method**	**Sample size**	**Patient characteristics & study location**	**Interventions**	**Outcome**
Bannerman and McDermott, 2011	Cross-sectional observational study using standard cup weights	30 (15 control)	Residential care (UK)	Normal diet vs TMD	Patient on TMD had lower total daily fluid intake than patients on a normal diet. Only 6.7% of patients on a modified diet met their daily fluid requirements compared to 33.3% of patients on a normal diet.
Rosler *et al*, 2015	Non-blinded single-subject non-randomized controlled trial	161 +30 controls	Hospital acute geriatric inpatients (Germany)	Water vs sliced apple vs pureed apple	Signs of water aspiration are more common than signs of aspiration when eating a slice of an apple. Signs of aspiration when eating apple puree are rarely seen.
Massoulard *et al*, 2011	Cross-sectional observational study	87	Residential care (France)	Normal diet vs minced diet vs mixed diet	Patients on TMD tended to have lower energy intake and protein intake compared to normal diet.
Leder *et al*, 2013	Non-blinded single-subject randomized trial	84	Hospital in patients who aspirate on thin but not thickened fluids (USA)	Moderately thick vs extremely thick fluids	Individuals who swallowed puree consistency without aspiration but exhibited aspiration with thin liquid ingested both nectar-like and honey-like thickened liquids with 100 % success at the time of testing as well as 24 hours after testing.
Keller *et al*, 2012	single-blinded single-subject randomized controlled trial with 9-month follow-up	42	Continuing care facility and residential care (Canada)	Usual commercial bulk TMD vs mixed commercial bulk vs mixed commercial bulk	Achievement of initially prescribed weight goal of gaining weight, maintaining weight, and losing weight.

PTMD = Texture modified diets, UK = United Kingdom, USA = United States of America, VFSS = Video fluoroscopic swallowing studies

Prevalence of texture modified food

There were studies of which the main objective was to find the prevalence of using TMD among older adults as in studies by Torres *et al*. (2019), Taniguchi *et al*. (2014) and Massoulard *et al*. (2011) (Table 2). The use of TMD more likely to have less detrimental effects including choking, feeding dependency, esophageal disease, poor dentition, refusal to eat, and cognitive deficits.

Aspiration and related pneumonia

There were five studies that included subjects with geriatric dysphagia. They have examined primary outcomes relating to aspiration in TMD (Table 2). Subjects had been recruited primarily from hospitalized patients care and residential care settings. One study (Li, 2015) investigated the relationship between aspiration related pneumonia in hospitalized older adults. Rosler *et al.* (2015) has investigated the frequency of aspiration with regard to the water, apple slices and pureed apples.

Nutrition and hydration

There were 3 studies out of 10 reported nutritional outcomes associated with TMD (Table 2). All of them were performed in residential care settings with an unspecified proportion of older adults suffering from swallowing problems. The studies including Massoulard *et al.* (2011), Bannerman & McDermott. (2012) compared daily energy and protein intake on normal diet versus TMD. Bannerman & McDermott. (2012) showed patients on TMD tended to have lower energy intake and protein intake compared to normal diet. Further, Bannerman & McDermott. (2021) illustrated that patient on TMD had lower total daily fluid intake than patients on a normal diet. Only 6.7% of patients on a modified diet met their daily fluid requirements compared to 33.3% of patients on a normal diet.

Most of the studies included in the review were on patients with signs of dysphagia. Seven articles out of 10 demonstrated the early signs of dysphagia in their studies. It was not possible to undertake a quantitative analysis of related results across studies due to the wide variation of instrumental methods used to measure swallowing behaviors, foods and liquids used in the selected studies.

DISCUSSION

In this systematic review, 136 journal articles were screened and selected 10 articles which contained original information related to the effectiveness of TMD for dysphagia among older adults. Very few of the articles explicitly explored effectiveness of texture modified diets. In assessing effectiveness of TMD for older adults with dysphagia, the studies identified are primarily in residential aged care facilities and in hospitals.

Studies that have shown the prevalence of TMD usage in older adults suffering from dysphagia described both the positive and negative impacts of TMD use. Torres *et al*. (2019), Oh *et al*. (2020), Bannerman & McDermott. (2011), and Li *et al*. (2015) discussed the effectiveness of various types of TMD for the older adults. Adherence to TMD varies depending on the environment, but there is no clear correlation with the type of food or fluid modification, age and severity of dysphagia. One study revealed that staff education and TMD availability improve the adherence to TMD in hospitalized patients (Bannerman & McDermott, 2011) and another study suggested that improved appearance of the TMD increases the adherence (Torres *et al*, 2019). In several cases, the authors used synonyms to describe the viscosities of the stimuli, such as "with a viscosity similar to water ", but failed to provide adequate evidence to support these descriptions. There were 4 studies: Oh *et al*. (2020), Li. (2015), Kyodo *et al.*

(2020), and Massoulard *et al*. (2011) which are concerned on an unparalleled stimulus. A total of nine items included a wide range of texture-modified foods, including spoon-thickened liquids, nectar-like liquids, honey-like liquids, pureed diets, water-like liquids, and regular normal diets. As solid food Rosler *et al*. (2015) used apple slices. In some investigations thin liquid compared to a slightly thick liquid also known as thicken with nectar and moderately thick liquid known as thick honey.

There were few studies coupled with nutrition and hydration in relation to TMD. Rosler *et al*. (2015) wanted to determine the amount of energy and protein consumed by patients with oropharyngeal dysphagia with the use of TMD. Diets thickened with nectar and pudding consistency were used. Total energy intake improved by 31% in the intervention group and also protein intake by 29% after 12 weeks of TMD consumption. Furthermore, according to them after taking TMD, body weight and BMI in the intervention group increased considerably (Massoulard *et al*, 2011). Despite pureed diets Taniguchi *et al*. (2014) pointed out that the minced diet is rich in protein and energy intake. Leder *et al*. (2013) showed the use of thickened fluids to maintain adequate hydration in older adults with dysphagia.

Contrary to the positive effects of TMD for older people, Taniguchi *et al*. (2014) and Massoulard *et al*. (2011) discussed the negative aspects of consistency-modified diets with regards to dysphagia in older adults. A number of studies have reported that people in residential care are unlikely to meet their recommended daily energy needs, and those with TMD have a lower daily energy intake than patients on a normal diet. Taniguchi *et al*. (2014) together with Keller *et al*. (2012) demonstrated that pureed diets are more like a baby food and are not attractive to the older adults and this leads to the loss of appetite. On the other hand, blended diets need to be consumed in large quantities to fulfill portion size and this results in a physiological burden for them (Taniguchi *et al*, 2014). It was also identified that patients in hospital and residential care with TMD do not maintain their daily fluid requirements. Furthermore, the studies suggests that the type of texture modification should be chosen based on the chewing ability and digestive disorders of the particular patient. Otherwise, using TMD without considering the exact requirement could result in negative health outcomes with a potential of worsening the quality of life of patient. Since TMD contains less water, it causes constipation in the older adults (Bannerman and McDermott, 2011).

The second key finding emphasized in this systematic review is the reduction of aspiration and aspiration related pneumonia in older adults due to TMD. One study (Oh *et al*, 2020) demonstrated the relationship between the swallowing analysis and aspiration prevention using texture modified food. They have used a video fluoroscopic swallowing studies (VFSS) in order to measure the swallowing physiology of geriatrics suffering from dysphagia. They suggest that in people with dysphagia, TMD reduces the risk of aspiration as seen on VFSS. Another study has used fiberoptic endoscopic evaluation of swallowing (FEES) to investigate the aspiration with regard to the puree consistency and thin liquids. It was noted that extremely thick fluids had significantly reduced risk of aspiration as modified fluid is thicker. Leder *et al*. (2013) emphasized that moderately and extremely thick fluids were equally effective for reducing aspiration. Rosler *et al*. (2015) showed that aspiration of water occurred more frequently than the apple slices and puree in patient with dementia and dysphagia.

One of the main reasons for aspiration and associated pneumonia is the accumulation of food debris in the pharyngeal area. The use of pureed diets is associated with the reduction of those pharyngeal residues and consequently reduces the risk of aspiration pneumonia in older adults with moderate to severe dysphagia (Kyodo *et al*, 2020). A study using four types of liquid stimuli showed that the pureed diet is effective rather than liquids similar to nectar and honey in preventing aspiration in older adults. The key finding of the study is that participants who swallowed the puree without aspiration, aspirated thin liquids (Leder *et al*, (2013). Furthermore, Leder *et al*. (2013) concluded that the use of thickened fluids improves the safety and efficacy of the patient's swallowing.

Another study conducted in China with the participation of older adults in a hospital specifically stated that eating posture plays an important role in the prevention of aspiration in patients with dysphagia. Changing the head or body posture helps relieving symptoms associated with aspiration when eating. This study emphasized that sitting posture is the best and sitting straight and slightly forward with the body and bending the neck forward allows food to easily enter the esophagus without entering the airways (Li, 2015). However, the position must be maintained and adapted according to the physical abilities of the individuals.

This systematic review has several limitations. The risk of bias was assessed according to the guidelines suggested by the Cochrane Bias Methods Group for randomized and non-randomized studies (Sterne *et al*, 2019). The RoB 2 tool was used to assess the risk of bias in the randomized trials and the ROBINS-I was used to assess the risk of bias in the non-randomized trials. In particular, the methods of each study were reviewed to see the presence of potential bias in terms of classification of interventions, selection of participants, missing data and reporting of results. Risks of bias were identified for most studies among the 10. Most of the studies had very small sample sizes and relatively short follow-up periods, resulting in bias in the selection of participants and measurement of reported results. The study participants were heterogeneous, with no studies consisting exclusively of subjects with geriatric dysphagia who were given thickened diets. Although five randomized control trials were included, some of these were undermined by the lack of an adequate control group which is explained by the authors based on ethical grounds. The sample consisted of patients who aspirated or did not get aspirated regardless of the intervention used.

The systematic summary of the literature has brought to light several important insights and allowed for a number of recommendations for further research. The current evidence is not strong enough to preclude TMD and liquids as a control group for ethical reasons in future randomized clinical trials. The relationship between TMD in older adults with dysphagia and clinically relevant outcomes in nutrition, hydration, aspiration and aspiration pneumonia needs to be further explored. Other important research goals are improving TMD as a nutritional alternative to the normal diet by enriching and examining alternative strategies for managing aspiration risk in older adults with dysphagia such as comfortable eating with better oral hygiene or use of free water protocols. More research is needed to guide clinical practice on aspiration management and the use of TMD in the older adults with aspiration and dysphagia.

In order to make comparisons and take firm decisions, more literature is necessary. The impact of TMD on the older adults (≥60 years) with regards to nutrition, hydration and aspiration is an area that would benefit from more in-depth research and could vary significantly between countries and in health care systems. Therefore detailed exploration on the relationship between TMD in older adults with dysphagia and the clinically relevant outcomes of nutrition, hydration, aspiration and aspiration pneumonia is needed. It can be aimed at finding contributing factors for dysphagia and reducing the incidence and severity of complications of dysphagia which lower the quality of life. Based on further studies, it is necessary to develop guidelines to manage the dysphagia among older adults.

CONCLUSIONS

Dysphagia disturbs the very foundation skills of eating and drinking of older adults. Texture modified diets are used in the management of dysphagia. This systematic review identified a number of key themes in relation to the dysphagia in older adults and a number of important gaps in literature.

Some major gaps include the understanding of the impact of liquid consistency and food texture on swallowing physiology, both in healthy and disordered older adults. The use of texture-modified foods and thickened liquids in the treatment of dysphagia in older adults is an area which need more research and provide strong grounds for clinical practice.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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Contribution of Dried Fish to Food and Nutrition Security in Sri Lanka: A review

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ABSTRACT

Dried fish is a widely consumed dietary source of macro and micronutrients, especially in low- and middle-income households. It is a pool of bioavailable high-quality animal protein with essential amino acids, essential minerals, vitamins, omega 3 and 6 fatty acids. Dried fish is generally acceptable to all regardless of region, religion, race, gender, and age across Sri Lanka. However, the role of dried fish production had been rarely elaborated on food and nutrition security in Sri Lanka. Therefore, this review aimed at delivering an overview of the contribution of dried fish towards food and nutrition security in Sri Lanka together with nutritional value of fish and dried fish products. The aim of dried fish production is to deliver a safe and wholesome final product to the consumer by preserving fish facilitating long shelf life. Sun drying, salting and drying, and smoked drying are the main dried fish processing methods. The contribution of dried fish is high in poor and marginalized communities in Sri Lanka. Dried fish provides a significant proportion of affordable and readily available animal protein to a large segment of the people in the country. Adequate emphasis should be given to enhance the dried fish production to meet the requirements. More investments are necessary to enhance the production of safe and quality dried fish.

INTRODUCTION

Malnutrition and hunger are among the most suffering problems in the world at present, especially in lower and middle-income countries (Bogard, 2017, Thilsted *et al.,* 2014). As Sri Lanka is still a developing country, malnutrition exists among rural poor and estate households more than the urban population (Abeywickrama *et al*., 2018; Reksten, *et al*., 2020). Furthermore, children under 5 years old as well as pregnant, and lactating women are highly vulnerable to under-nourished conditions (Amarasinghe, 2014). Anemia, iodine, zinc, vitamin A, folate, and calcium deficiencies are nutrient deficiency problems reported in Sri Lanka that were prevalent among low-income families (Reksten, *et al*., 2020, Abeywickrama *et al*., 2018; Weerahewa *et al*., 2018). Fundamental factors such as uncertainty in the politics and economy of the country, healthcare status, food culture, gender equality, education, and environmental issues play a critical role in the causal pathways of malnutrition (Abeywickrama *et al*., 2018). The significance of this global challenge is highlighted in the United Nations Sustainable Development Goals (SDGs), where goal two is designed to address ending hunger, achieving food security, improving nutrition, and ending all forms of malnutrition (Laborde *et al*., 2016).

Food and nutrition security is defined as the ability of all people to have physical, social, and economic access to sufficient, nutritious, and safe food to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education, and care (Bilali *et al*., 2019). Pervasive food and nutrition insecurity has emerged as a global humanitarian crisis during the coronavirus disease (COVID-19) pandemic. Across the world, fisheries have been identified as being an important component in achieving food and nutrition security, especially in less-developed countries including Sri Lanka (Khan *et al*., 2021). The fisheries sector in a country can contribute to food and nutrition security in two ways. On one hand, fish and related products are rich dietary sources of essential macro and micronutrients. On the other hand, it can be a direct nutrient source or an income source that can be used to buy other types of food for fishing communities (Emmanuel *et al*., 2019).

The fisheries sector in Sri Lanka plays a crucial role in the economy of the country contributing around 1.3% to the gross domestic production. Fish products are an important source of animal nutrients, providing nearly 50% of animal protein and 22.2% of animal fat (Fisheries Statistics, 2019). Direct and indirect employment is also provided to around 585,000 people (Fisheries Industry Outlook, 2018). In the year 2019, the marine sector contributes 415,490 MT for annual fish production while 90,340 MT is supplied by the inland and aquaculture sector. Per capita, fish consumption was around 16.6 kg/year (Fisheries Statistics, 2019).

Dried fish is an important commodity consumed for centuries in Sri Lanka which plays a significant role in nutrient security, livelihood, and foreign exchange similar to fresh fish production. Dried fish supports to minimize postharvest losses of fresh fish while giving a value-added product (Koralagama *et al*., 2021). Poor handling and storage of fish allow rapid postharvest deterioration limiting the availability. Consequently, salting, smoking, and/or sun-drying of fish are used to preserve and produce a microbiologically stable products at a reasonable cost (Guizani *et al*., 2008). Dried fish is considered the poor man's protein because it is one of the main affordable sources of animal protein compared to other animal proteins (i.e., meat, dairy, and eggs) for the underprivileged community in low-income groups, especially the people living in areas other than the coastal belt (Aall, 1982; Dona *et al*., 2018). Additionally, due to the prevailing COVID-19 pandemic situation in recent years, the demand for shelf-stable dried fish products has spiked at households as it is a non-perishable food item (Mandal *et al*., 2021). It is acknowledged that increased dried fish supplies are needed to meet the growing food demand in Sri Lanka. However, there is limited information regarding the contribution of dried fish consumption to overall food and nutrition security among Sri Lankans. This review was to present an overview of the contribution of dried fish towards food and nutrition security in Sri Lanka while describing the nutritional value of dried fish products and consumption behavior of the Sri Lankans.

MATERIALS & METHODS

The review focused on the link between dried fish and food and nutrition security in Sri Lanka and their contribution to selected areas of four dimensions of food security: food availability, food access, utilization, and stability (Figure 1). Quantitative and qualitative research articles fulfilling the following criteria were identified; written in English, published after the year 2005, presenting local and international data, available online, and relevant to one of the selected topics highlighted in Figure 1. Previously published research articles (between 2007 and 2020) relating to fish and dried fish nutrition towards human health were browsed using reputed browsing tools and websites such as Google scholar, Medline, Science Direct, and Web of Science. To reach for more relevant articles, a reference list of major studies was examined while using terms regarding the nutrient composition of dried fish and dried krill, nutrient composition of fish, fish and dried fish consumption, dried fish-based product development, and malnutrition status of Sri Lanka as keywords. This review also includes data published by annual reports and statistics of the Ministry of Fisheries and Aquatic Resource Development (MFARD), National Aquatic Resources Research and Development Agency (NARA), Department of Census and Statistics, Food and Agriculture Organization (FAO) in recent years.

RESULTS

Dried fish for food and nutrition security in Sri Lanka

Availability of dried fish to strengthen food and nutrition security in Sri Lanka

Fish and its processed foods including dried fish and canned fish are the most frequently consumed animal protein sources in Sri Lanka, irrespective of socioeconomic status or locality. Dried fish is not only a value-added commodity derived from fish, but also it is an important source of nutrition among Sri Lankan cuisines. It is consumed as a main dish as well as a flavor-enhancing condiment in many dishes (Koralagama *et al*., 2021). Until 2012, it remained the second highest animal origin food product consumed per capita after fresh fish (Department of Census and Statistics, 2016). However, dried fish prices have increased considerably since 2012 compared to fish and chicken prices, and consequently dried fish consumption has fallen to third place (Fisheries Industry Outlook, 2018). However, it is still significant as an animal origin protein source in low-income households, particularly in the island’s rural areas, dry zone, and hill-country regions (Krishnal and Dayaani, 2014) as it is a low-cost, readily available, and shelf-stable substitute compared to other animal protein sources such as chicken, seafoods, eggs, and dairy products (Dona *et al*., 2018). The most demanding dried fish variety in Sri Lanka is sprats (anchovy) followed by skipjack tuna, shark, smooth belly sardines, and Thalang queen fish (Wickrama *et al*., 2021; Koralagama *et al*., 2021). Average fish consumption is 16.6 kg/year in 2019 in all sectors. Monthly expenditure on dried fish data showed estate households expenditure is more compared to the urban and rural communities (Dona *et al*., 2018). Demand for dried fish is increased by the religious and cultural barriers to the consumption of meat and the unavailability of other animal protein sources (Koralagama *et al*., 2021). Most of the local consumers have declared that price fluctuation as the main problem for purchasing dried fish. In addition, poor production facilities, disorganized market facilities, and poor-quality products are existing problems that affect the availability of dried fish in Sri Lankan market (Krishnal and Dayaani, 2014).

In 2019, the total dried fish supply to Sri Lankan market was 89,849 MT and from that, 54,880 MT was domestically produced, and 34,969 MT was imported (Fisheries Statistics, 2019). Thus, nearly 65% of local dried fish demand is produced within the country, and the remaining was imported mainly from Maldives, Pakistan, Thailand, India, Indonesia, and United Arab Emirates. Anchovies (sprat) share 70% of total imports of dried fish and it is considered the major fishery product imports to the country (Fisheries Industry Outlook, 2018). Marine and inland are the major two sectors of dried fish production in the country. Marine dried fish production far outpaces inland production and with little research on inland dried fish production.

Even though processing of marine dried fish is practiced in all coastal belt areas in Sri Lanka, on a large scale, it is implemented in Trincomalee, Mannar, Kalpitiya, Chilaw, Jaffna, Beruwala, Negambo, Mulathivu, Ampara, Hambanthota, Galle, Kaluthara and Batticalo. Inland dried fish production is mainly carried out in Ampara, Anuradhapura, Polonnaruwa, Minneriya, and Monaragala in natural reservoirs and tanks (Fisheries Industry Outlook, 2018). Table 1 depicts the marine and freshwater fish varieties used to produce dried fish in Sri Lanka. As presented in Table 1, the main marine dried fish species produced in Sri Lanka are sprats, Katta, Balaya, Keeramin, Seer, and Maduwa. Most freshwater fish are low in price because they are small in size, and the bone percentage is high compared to flesh. Therefore they are used for drying. Tilapia, Catfish, Pearl spot Cichlid, and filamented Barb are the inland fish varieties used for drying (Fisheries Industry Outlook 2018; Koralagama *et al*., 2021). In Sri Lanka, it is estimated that 14% of the harvested fish is well-preserved using simple processing techniques such as sun drying, solar drying, salting, smoking, and fermentation, collectively known as "dried fish."

Figure 2 illustrates the two different methods of fish drying and processing methods in Sri Lanka. Salt and fish are used as the main raw materials for the processing dried fish (Boziaris, 2014). Low-quality fish (which are brought in by multiday boats late/ "Dawal malu" or fish at the bottom of net/ "Yata malu") and part of excess fish supply in peak seasons are mainly used for dried fish production (Koralagama *et al*, 2021). Additionally, fish susceptible to spoilage and difficult to sell at the fisherman level is processed into dried fish (Agustini *et al*., 2009). Sun drying is a conventional method of drying fish; under the hot sun without adding salt. Generally, multiday boats use this method to make sun-dried fish with initial catches of their harvest, locally these are called "bottu karawala", boat-dried fish (Koralagama *et al*., 2021).

The traditional drying and salting method of preserving fish continues to be very popular because it produces such great flavor, long shelf life, and more expected quality attributes of consumers (with or without sun) (Surendra *et al*., 2015,

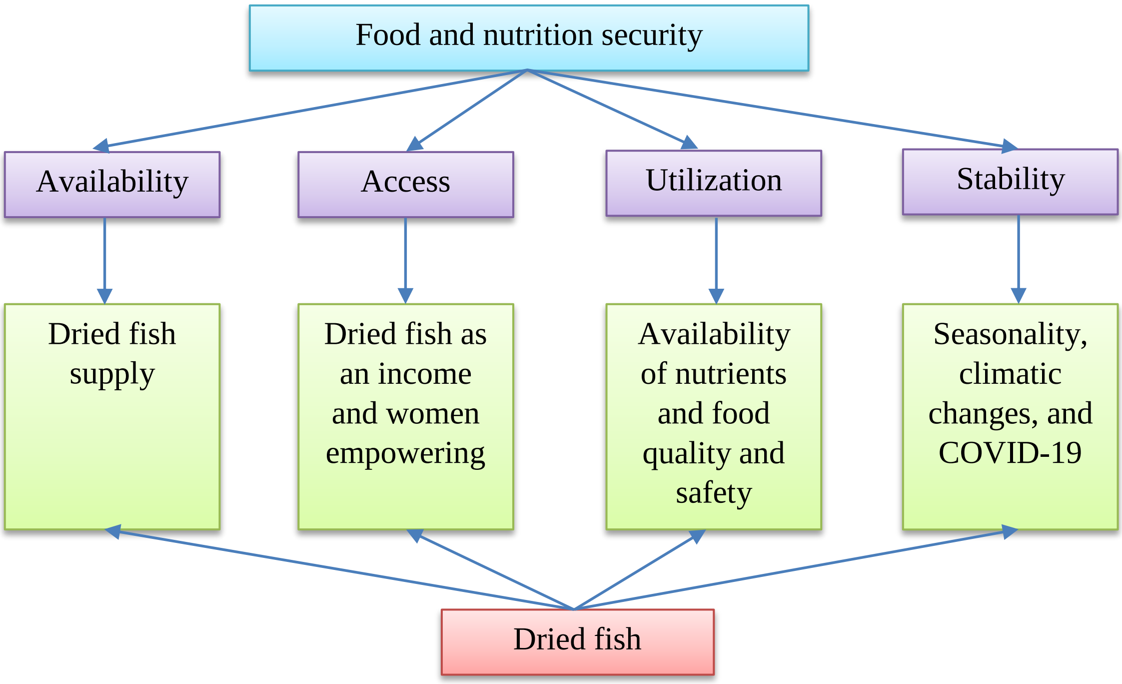

Figure 1. Conceptual framework for the review article, the four pillars of food security (Bilali *et al.*,2019) and selected focus areas related to dried fish and food and nutrition security in Sri Lanka

Boziaris, 2014). Maldive fish or in other words cooked, smoked, and hard dried Tuna variety fish is another popular type of dried fish in Sri Lanka. Lengthy smoking is based on the principle of reducing the internal water content. Smoke particles provide an added flavor, color, and taste to the product and it also has antioxidant and antimicrobial properties confirming the preservation of fish (Abraha *et al.*, 2018).

Contribution of dried fish industry on food accessibility in Sri Lanka

The growing economic inequality has serious implications for food and nutrition and emphasizes the importance of having access to affordable, nutritious foods. The role of dried fish is crucial in this regard, as it is available throughout the country at relatively low prices, and can be purchased in small quantities. According to the estimates of Household Income and Expenditure Survey (2016), the average monthly consumption of dried fish per Sri Lankan household is 1.1 kg and dried fish provides 60% of the total animal protein intake (Olaidipo and Bankole, 2013).

Livelihood built up with the dried fish value chain helps to generate income and allows people to access nutritious foods. The dried fish industry is mainly carried out as cottage level industry by women in the fishing communities as an extra source of income (Wickrama *et al.*, 2021). Women in the coastal belt in Sri Lanka play a vital role in food and nutrition security, making smoked and dried fish available in urban and rural markets at relatively affordable prices. Dried fish can be stored in households lacking electricity, refrigerators, and freezers.

Although women's roles in the dried fish industry are considered essential, these women's communities have limited access to funding, education, and institutional support compared with their male counterparts, which limits the role of women in decision-making and their opportunities for enterprise expansion in the fisheries sector (Koralagama *et al*., 2021). Additionally, the main obstacles to dried fish processing in Sri Lanka are high labor cost, inadequate fish supply for processing, especially during the off-season, uncertain weather, and poor storage facilities. Women's engagement in dried fish processing is the lowest in Muslim fishing communities.

On the other hand, women's engagement in dried fish processing appears to be highest in Sinhala Catholic and Tamil Hindu fishing communities in Sri Lanka (Yuganthan *et al*., 2019). Moreover, accessibility to fresh fish (key raw material), beach (location), market (revenue), finance (decision making), as well as lack of social recognition and powerlessness are reported as constraints by women dried fish processors in Sri Lanka (Koralagama and Bandara, 2018). Despite these limitations, the purchasing power from selling dried fish (i.e., increased access) resulted in a greater proportion of income being spent on other staple nutritious food when women were engaged in these activities.

Contribution of dried fish to the nutrition security in Sri Lanka

This section highlights three important dimensions of dried fish as food: 1) the bioavailability of essential nutrients in dried fish, 2) the contribution of fish to nutrition security for vulnerable populations in Sri Lanka and, 3) food quality and safety concerns regarding dried fish handling and consumption.

Bioavailability of essential nutrients in dried fish

Dried fish is rich in highly bioavailable nutrients which are beneficial for human health including animal protein/essential amino acids, essential polyunsaturated fatty acids, and micronutrients such as vitamins and minerals with a low amount of calorie (Gephart *et al*., 2020, Balami *et al*., 2019). The nutritional composition of dried fish varies according to sex, age, season, habitat, region, water temperature, type of dietary ingredients, and abundance of available fish (Reksten, *et al*., 2020, Abraha *et al*., 2018, Boziaris, 2014).

Table 2 shows the proximate composition of commonly consumed dried fish species. The water activity of dried fish is nearly 0.73 (Surendra *et al*., 2015) while water content is nearly 15-40% (Sachithananthan, 1977), 18.23-24.46% (Azam *et al*., 2003), 29.25-34.43% (Islam *et al*., 2013) and 14.06-24.58%. Depending on the relative humidity of the surrounding environment and the fish species, water content of dried fish gives different values (Flowra *et al*., 2012). Except for moisture content, other nutrients show lower values in fresh fish than in dried fish (Pal *et al*., 2018). Therefore, dried fish is identified as a nutrient-dense product. Moreover, it is reported that the nutritional value of 1.0 kg of dried fish is higher than 1.0 kg of chicken in wet weight (Koralagama *et al*, 2021).

As an animal origin protein source, protein in dried fish is known as more easily digestible than plant protein while improving the digestibility of plant protein (Emmanuel *et al*., 2019). Dried fish is rich in all essential amino acids, especially methionine and cysteine which are less available in plants. Further, the digestibility of fish protein is higher nearly 85-95% than other sources of proteins (Balami *et al*., 2019, Jag Pal *et al*., 2018).

A large portion of fish lipids contains unsaturated fatty acids and lipid-soluble vitamins (A and D). Omega 3 and omega 6 are two types of essential fatty acids and cannot be efficiently synthesized in the human body (Pal *et al*., 2018). Polyunsaturated fatty acids make fish a nutritionally important food.

Table 1. Marine and freshwater fish varieties used to produce dried fish in Sri Lanka

Scientific name	English name	Sinhala name	Expenditure on dried fish (LKR)†	Dried fish consumption (g)‡
Marine fish				
Stolephorus sp.	Anchovy species (sprats)	Haalmessa	77.90	128.15
Amblygaster cluepeoides	Smoothbelly sardinella	Keerameen	13.26	20.11
Amblygaster sirm	Trenched sardinella (herring)	Hurulla	3.22	6.01
Leiognathus sp.	Pony fish species	Karalla	-	-
Rastrelliger kanagurta	Indian mackerel	Kumbalava	-	-
Decapterus macrosoma	Shortfin scad	Linna	-	-
Katsuwonus pelamis	Skipjack tuna	Balaya	22.19	29.77
Scombroides lysan	Double-spotted queen fish	Katta	19.85	19.69
Carcharhinus sp.	Shark	Mora/Keelan	19.85	22.15
Clarias thalassinus	Giant catfish	Anguluwa	7.75	10.85
Scomberomorus commersoni	Narrow-barred Spanish mackerel (Seer)	Thora	-	-
Harpadon nehereus	Bombay duck	Bombili	-	-
Dasyatis sp.	Sting ray	Maduwa	-	-
Caranx ignobilis	Giant trevally	Parawa	1.11	1.51
Penaeus sp.	Shrimp/prawn	Issa	1.94	2.41
	Krill	Kooni	-	-
Freshwater Fish			2.22	3.86
Oreochromis mossambic	Tilapia	Mozambique Tilapiya	-	-
Clarias sp.	Catfish	Magura	-	-
Puntius filamentosus	Filamented barb	Pethiya	-	-
Etroplus suratensis	Pearl spot cichlid	Koraliya	-	-
Oreochromis niloticus	Nile tilapia	Batta	-	-
Glossogobius giuris	Bar eyed goby	Weligouwa	-	-
Channa striatus	Murrel	Loola	-	-
Hyporham	Half beak	Morella	-	-

†Average monthly expenditure per person in 2016
‡Average monthly consumption per person in 2016
(Source: Department of Census and statistics - 2016, Fisheries Statistics -2019, Koralagama et al, 2021).

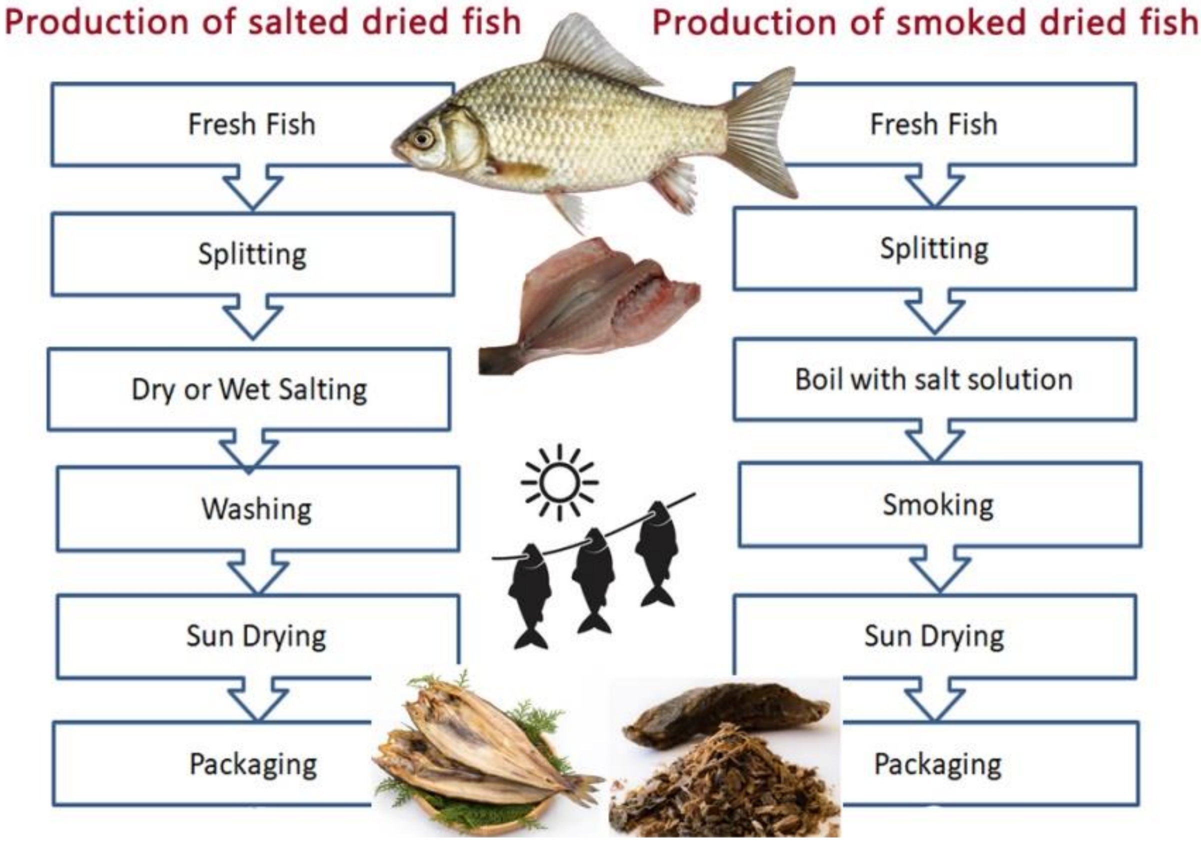

Figure 2. Overview of processing methods of dried fish

Fish including Trenched sardinella, Gold-striped sardinella, other *sarinella sp*., and Mackerels supply sufficient amounts of omega-3 fatty acids by eating them at least twice a week (Ministry of Health Sri Lanka, 2011). Polyunsaturated fatty acids are very crucial during the pregnancy period to improve the cognitive development of the child.

Docosahexaenoic acid (DHA) has been found to be essential for the development of the brain and central nervous system in children while eicosapentaenoic acid (EPA) is important in cardiovascular health (Balami *et al*., 2019, Ministry of Health Sri Lanka, 2011). Fat in fish is helpful for the prevention of cancer, depression, and atherosclerosis. They are known to prevent many diseases such as skin diseases, asthma, arthritis, diabetes, autoimmune disorders, and enhance the immune system (Pal *et al*., 2018, Ministry of Health Sri Lanka, 2011).

Dried fish, more particularly small fish are rich in bioavailable minerals and these minerals are easily absorbed by the body. Calcium, iron, iodine, zinc, and selenium are the main minerals in fish. Other than these, phosphorus, sodium, potassium, and fluorine are present in fish and dried fish products. Calcium is a crucial mineral for bone health, and it is supplemented during the pregnancy period to maintain the health of both fetus and mother (Kwasek *et al*., 2020). Small fish can be added to meals as fried fish which are rich in calcium. Calcium is a key component for the formation and the maintenance of teeth and bones and helpsto minimize the risk of osteoporosis in adults and rickets in children (Ministry of Health Sri Lanka, 2011). Further, it is important for the proper functioning of

Table 2. Proximate composition values for dried fish

Fish species considered	Crude protein (%)	Crude fat (%)	Total minerals (%)	Reference
Dried haddock	75-80	0.6	5.6 Salt - 1.2	Jonsson *et al*., 2007
Dried sprats	-	-	Salt - 11.78	Surendra *et al*., 2015
Dried catfish	-	-	Salt - 12.48	
Dried tuna	-	-	Salt - 14.01	
Dried fish (Using 17 species)	40-50	Over 4	16.1 - 30.6	Sachithananthan, 1977
Sardinella sp	46.7	1.1	17.8	Sachithananthan, 1977 (Proximate composition of dried fish)
Amblygaster sirm	46.3	4.4	21.3	
Tachysurus sp.	45.1	2.9	21.1	
Exocoetus sp.	44.9	6.5	27.9	
Chorinemes lysan	44.2	2.3	21.1	
Tilapia mossambica	41.4	3.3	40.6	
Rastrelliger kanagurta	45.3	2.0	22.5	
Katsuwonus pelamis	45.0	1.7	17.6	
Dussumieria acuta	43.5	5.4	18.4	
Anchoviella indica	52.8	5.8	25.2	
Dried fish (using 14 species)	40.69 - 68.09	2.97 - 26.13	5.08 - 16.02	Azam *et al*., 2003
Dried fish (using five species)	53.45 - 76.39	2.31 - 21.54	11.21 - 28.15	Flowra *et al*., 2012
Dried fish (using four species)	32.02 - 41.38	3.21 - 14.03	20.14 - 24.40	Islam *et al*., 2013
Dried krill / "Kooni"	54.6 - 71.6	4.5 - 9.2	22.0 - 40.7	Abeywickrama and Attygalle, 2014

nervous system and muscles (Pal *et al*., 2018). All red fish, sardinella, and dried fish supply heme iron which shows a better absorption compared to plant-origin non-heme iron (Ministry of Health Sri Lanka, 2011). It facilitates hemoglobin synthesis and useful in the prevention of anema (Kwasek *et al*., 2020, Pal *et al*., 2018; Abeywickrama *et al*., 2018). Dried fish also counteracts the effect of inhibitors, such as phytates, and thus co-ingestion enhances the absorption of non-heme iron and zinc from plant foods.

Small marine fish is an excellent natural source of iodine, zinc, and selenium. The purposes of iodine for humans are balancing thyroid function and regulation of body metabolism. Selenium is a trace element with antioxidant properties (Pal *et al*., 2018) and important in preventing cardiovascular diseases. Prevention of cancers and stimulation of the immune system are the other important roles of selenium. Zinc is necessary for the growth and the proper functions of immune system (Kwasek *et al*., 2020).

High levels of vitamins including fat-soluble (i.e., Vitamins A and D) and water-soluble (i.e., Vitamin B12) vitamins are present in dried fish. However, the bioavailability of vitamin varies among fish species. Large amounts of vitamins A and D are known to be stored in the liver of many fish species (Balami *et al*., 2019). Fatty fish have high amount of vitamin D than lean fish due to their fat-soluble nature (Kwasek *et al*., 2020, Jag Pal *et al*., 2018). Vitamin A is sensitive to sunlight and heat (Abraha *et al*., 2018). However, the effect of processing methods on micronutrient levels in fish is yet to be thoroughly elucidated. To maximize the utilization of dried fish in Sri Lanka, both selection of the fish species and the processing methods are important factors which determine the nutrient density and preservation. However, research findings on this area is still not well-established.

Contribution of fish to nutrition security in Sri Lanka

There are many dried fish recipes in Sri Lanka, which mainly include dried fish curry with coconut sauce (karawala/halmessan hodi), deep frying, stir-frying and pickling etc. (Koralagama *et al*., 2021). Dietary enrichment of toddlers, adolescents, pregnant and lactating mothers as well as elderly people's main meals with dried fish products is a common practice in Sri Lanka. However, scientific literature on the topic remains scarce. According to research conducted in Bangladesh, fish-based complementary food (i.e., dried fish chutney, dried fish powder) supply desirable amount of nutrients including iron, zinc, essential fatty acids, and protein for infants, young children, pregnant and lactating women (Islam *et al*., 2013). For instance, one serving (10 g) of fish powder in the diet supplies more than 20% of recommended daily calcium requirement and 37% of DHA. One serving (30 g) of fish chutney gives more than 40% and 50% of recommended daily calcium requirement for pregnant women and lactating women, respectively. Research in Africa showed, dried small fish-based recipes can deal with micronutrient deficiencies that occur during the first 1000 days of life (Byrd *et al*., 2021).

Quality and safety aspects of dried fish

While dried fish contains a wide array of nutrients, they are also a source of contaminants. Dried fish have recently been identified and confirmed as a significant source of pathogens and chemical contaminants that pose a potential threat to human health in Sri Lanka (Surendra *et al*., 2015). Microplastic contamination (Reksten, *et al*., 2020), the presence of mycotoxin / aflatoxin (Deng *et al*., 2020), histamine (Ginigaddarage *et al*., 2018, Surendra *et al*., 2015), accumulation of heavy metals (Hg, Pb, Cd) and residues of agrochemical substances (Jinadasa *et al*., 2018) and formalin contaminations (Hanayani and Mutiara, 2020) have been identified as major health hazards associated with dried fish. Government has enacted laws and regulations to ensure standard production of dried fish to make those safe for human consumption (Food Regulations, 2020). Sri Lanka Standards Institution (SLSI) has prepared national-level specifications for dried fish (SLS 643: 1984 (Surendra *et al*., 2015) and Maldive Fish (SLS 811: 1988). However, locally produced dried fish are identified as safe for human consumption than imported products (Surendra *et al*., 2015).

Apart from contaminants, salt concentration of salted dried fish is critical for human health because overconsumption of salt beyond the recommended levels can have a direct impact on the development of non-communicable diseases including hypertension, strokes, and cardiovascular diseases. According to the CODEX recommendation (2013) for salt concentration in dried fish, the content should be close to 12% (Dharshini *et al*., 2018). Maximum salt content recommended by Sri Lanka's Food (Fish and Fish Products, 2020) Regulation was

12-30% for whole dried fish, 10-35% for split dried fish, and 2-16% for dried fish fillets. It has been reported that 91% of imported dried fish contained higher amount of salt compared to local products (54%). This problem can be avoided by soaking dried fish well before cooking (Ginigaddarage *et al*., 2018).

Nutritional constituents and sensory properties of fish can be changed due to drying and smoking of fish mainly through denaturation of protein and loss of vitamin A (Abraha *et al*., 2018). If protein denaturation and lipid oxidation take place, it eventually reduces the nutritional value of dried fish, especially PUFAs (Boziaris, 2014, Guizani *et al*., 2008). Sun-dried fish are slightly less quality due to the breakdown of certain nutrients in sunlight and direct exposure to contaminants. Due to the quick drying in initial stage, a relatively moisture impermeable layer is formed on the surface of fish and inner moisture of the fish may cause rapid spoilage. On the other hand, artificial drying methods contribute to preserve the dried fish in good quality and safety under controlled temperature conditions (Boziaris, 2014).

Stability of dried fish supply in Sri Lanka

Dried fish production in Sri Lanka is seasonal due to seasonal variations in fish availability. This led to price fluctuations of dried fish, which has the greatest impact on poor inland dried fish consumers. Additionally, seasonal fluctuations in fish availability have a considerable, cascading effect on economic stability and the livelihoods of dried fish producers in the marine and inland sectors (Wickrama *et al*., 2021).

Climatic changes and manmade disasters impose a significant impact on the livelihood (Rabbani *et al*., 2010) of coastal dried dish producers which affects the continuous supply of dried fish and the income of fishermen. For instance, the lowest Sri Lankan dried fish production was recorded in 2005, following the devastation of tsunami in December 2004. The destruction caused to the fisheries industry drastically reduced the overall fish production in 2005. Moreover, it was reported that people in the costal belt refrained from consuming fresh fish for some time after the tsunami (Jayantha and Hideki, 2006). Moreover, in early 2021, an environmental disaster caused by the slow sinking of a fire-ravaged cargo ship that had been loaded with chemicals was also affected the fishing community, especially in Colombo and Gampaha districts in Sri Lanka. As a result of this disaster, Sri Lankan consumers refused to consume fish and dried fish.

Role of dried fish during the Covid-19 pandemic in human nutrition and health

Marine fishery takes a major role in local fish consumption. The availability of fresh fish is an issue when fishing activities are disturbed by unexpected situations. Therefore, dried fish is used as one of the best nutritional alternatives for fresh fish to fulfill human nutritional requirements (Flowra *et al*., 2012, Jonsson *et al*., 2007). Covid-19 pandemic situation impacts almost all the sectors in the world disrupting the continuous supply of food. During the lockdown period people faced difficulties to access the nutritious food sources. Nutritionists encourage people to consume healthy foods rich in omega-3 fatty acids, minerals (zinc, selenium, iron etc.), and vitamins (A, B, C, and D) for the proper functioning of immune system (Coelho-Ravagnani *et at*., 2021). Continuous supply of fresh fish to inland areas was disturbed and people were reluctant to dealing with outsiders frequently during the pandemic. Therefore, rural poor mostly moved towards dried fish instead of fresh fish, because of the easy storage of dried fish. Dried fish is recommended as a nutritious food, a rich source of protein and micronutrients and had been used frequently during the quarantine period by confirming food and nutrition security in the country (Khan *et al*., 2021).

CONCLUSIONS

Dried fish provides a significant proportion of affordable and readily available animal protein to a large segment of the people in the country. More emphasis should be given to enhance domestic dried fish production. However, to secure dried fish availability, investments should be made in the fish value chain. Initiatives must be taken to improve the productivity as well as quality and safety standards of the local dried fish industry to ensure the continuous supply of safe and nutritious dried fish. Upgrading of processing systems should address the areas of using of high-quality fish, suitable fresh fish storage facilities, practicing cutting, cleaning, and drying under hygienic and controlled conditions, proper packaging and storage of finished products. Effective management of dried fish industry is essential for food, economic, and nutritional security in Sri Lanka.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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