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Development of a High-Calorie Nutritional Porridge Formula Enriched with Vitamin A and Iron for Primary School Children

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ABSTRACT

Malnutrition is a major problem among school children in Sri Lanka. This is mainly because children are used to having ready-to-eat foods for breakfast, which have low nutritional value and an imbalance in their nutritional profile. A wide range of nutrition interventions are ongoing to address this matter. The present study aimed to produce high-calorie nutritional porridge enriched with vitamin A and iron and evaluate the nutritional quality of the porridge. Both fresh and dry formulas were developed in this study. Selection of raw materials was done by considering the nutritional value and the organoleptic properties of the ingredients. This formula contains Pachchaperumal and Rathu Heenati as two traditional rice varieties (*Oryza sativa*), Medeeri (*Panicum miliaceum*), Soya Bean Seeds (*Glycine max*), and Green Gram Seeds (*Vigna radiata*) as the cereal mixture. For the vegetables, Pumpkin (*Cucurbita maxima*), Gotukola (*Centella asiatica*), and Spinach (*Spinacia oleracea*) were selected due to their high beta-carotene and iron content. The porridge mixture was further analysed for its physical and chemical properties, sensory characteristics, and shelf-life studies. The caloric value, protein, fat, dietary fiber, available carbohydrate, and ash content of the final product (per one serving, 200 mL) were 78.525 Kcal, 3.171 g, 3.925 g, 1.943 g, 7.629 g, 1.942 g, respectively. The final product contained 1.1 g, 16.4 mg, 6.4 mg, and 1.2 mg of Na, Ca, Fe, and Zn, respectively. Also, it contained 30.0 µg, 8.6 mg, and 0.4 mg of β-carotene, Vitamin B3, and Vitamin B6, singly. Shelf-life studies exhibited that the dry porridge mix remained stable at room temperature (27 ± 2 °C, RH=74%) for up to three months in double-laminated (Met Pet/ LDPE aluminum foil) packaging. This concludes that the developed porridge mix offers a nutritious, child-friendly breakfast made from locally available grains, vegetables, and spices, which will address the need for healthy calorie intake along with vitamin A and iron, while reducing dependence on imported and refined products.

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1. Introduction

Sri Lanka is a developing country in the South Asian region. Due to the present socio-economic background, children are used to having ready-to-eat foods as their breakfast. Most of the time, they are consumed junked foods, which has low nutritional value and an imbalance of nutrients, which causes health risks. Food intake influences the nutritional status of an individual to a great extent. It is one of the critical factors responsible for malnutrition, particularly in children under ten years of age [11].

According to the National Nutrition Surveillance System of Sri Lanka, the current situation of underweight among children under ten years has become 22%, chronic malnutrition (stunting) is 18%, and acute malnutrition (wasting) has become 16% [16]. Overweight and obesity are emerging problems, particularly among the school children in urban areas. The current prevalence of overweight is 10%. Micronutrient deficiency is another aspect of nutrition deficiencies affecting the country, which predominantly include iron and vitamin A deficiencies. About 29% of the children are suffering from vitamin A deficiency, and a similar proportion is afflicted with iron deficiency. Also, 30% of the pregnant mothers are anemic. This leads to a high risk of low-birth-weight babies, which currently stand at 16.6%. Apart from those, non-communicable diseases such as diabetes mellitus, hypertension, coronary heart diseases, and certain types of cancers are showing an increasing trend [13,16,17,19].

The present socio-economic transformation has led to a doubling of the nutrition burden. Mothers have limited time with their children; hence, food preparation and feeding become an issue. On the other hand, modern-day customers in some segments are highly conscious about the health hazards, and they pay more action on functional foods.

A wide range of nutrition interventions are ongoing to address this matter. Due to the busy lifestyle of families, preparation of “Kola kada” at the household level has become less popular. Therefore, an attractive instant family pack of porridge will be developed for the mass market. Dry formula will help to reduce the preparation time and increase the nutritional status at the family level.

Considering the Vitamin A and Iron deficiency among schoolchildren, a high-calorie nutritional porridge will be developed using locally available ingredients to supply primary school children all over the country. The selection of ingredients for the formulation depends on the nutritional content of staple foods, dietary habits of the people, other socio-economic aspects as determined by the national authorities dealing with nutrition, availability and cost of raw materials and other ingredients, etc. [4,5].

Therefore, considering the aforementioned circumstances, the present study was designed to develop a processed supplementary food product (nutritional porridge) that is nutrient-dense, matching the local taste, using the local raw materials, and affordable for the target market.

2. Methodology

2.1 Selection of Raw Materials

2.1.1 Preparing grain mix

Several locally available raw materials were selected according to their nutritional value, use for porridge preparation in locally household level, sensory properties, and local availability [6,7,11,12, 14,15].

Cereal mix –	Pachchaperumal
	Rathu Heenati
	Proso millet (<i>Panicum miliaceum</i>)
	Soya Bean Seeds (<i>Glycine max</i>)
	Green Gram Seeds (<i>Vigna radiata</i>)
	Dhal (<i>Lens culinaris</i>)

Blending was practiced in different ratios, considering nutritional value and sensory quality.

2.1.2 Preparing vegetable and spicy mix

Spicy mix - Pepper (*Piper nigrum*), Mustard (*Sinapis hirta*), Curry Leaves (*Murraya koenigii*), Coriander (*Coriandrum sativum*), Fenugreek (*Trigonella foenum-graecum*), Cumin Seeds (*Cuminum cyminum*), Garlic (*Allium sativum*), Red Onion (*Allium cepa*), Ginger (*Zingiber officinale*), Cinnamon (*Cinnamomum zeylanicum*)

Vegetables - Pumpkin (*Cucurbita maxima*), Centella leaves (*Centella asiatica*), Spinach (*Spinacia oleracea*)

2.2 Preparation of Formula for the Porridge

2.2.1 Preparation of cereals

Proso millet seeds were screened for stones, rots, and other defects and thoroughly washed and cleaned to remove the dust and other foreign materials. Then it was dried in a dehydrator at 60 °C for 12 hr. (until the moisture content was less than 10%). Finally, seeds were ground using a pin mill (with a 0.5 mm sieve). Powder of Proso millet seeds was stored in an airtight container before use.

2.2.2 Preparation of pulses

Green gram seeds and soybean seeds were thoroughly washed and cleaned to remove the dust and other foreign materials. Cleaned seeds were soaked in water for five hours. Then the seeds were dried in a tunnel dryer at 60 °C for 12 hr. (until the moisture content was less than 10%). Finally, seeds were ground using a pin mill (with a 0.5 mm sieve). Powder of each seed was stored in airtight containers separately.

2.2.3 Preparation of spicy mix

All the spices were screened for stones and other defects, and thoroughly washed and cleaned to remove the dust and other foreign materials. Pepper and Mustard seeds were dried in a dehydrator at 50 °C for 8 hr and ground using a Fritsch mill (with a 0.5 mm sieve). Coriander, fenugreek, cumin seeds, and cinnamon were also dried in a dehydrator at 50 °C for 8 hr, roasted for five minutes, and ground using a Fritsch mill (with a 0.5 mm sieve). Garlic, red onion, and ginger were peeled, cut into thin slices, dried in a dehydrator at 50 °C for 8 hr and ground using a Fritsch mill (with a 0.5 mm sieve). Curry Leaves were specially treated to retain their green colour during processing. Leaves were removed from their stems, and they were immersed in solution for five minutes (1% SMS, 1% MgCO₃, and 3% Citric acid solution, where the pH was maintained at 3.0 – 3.5) [11]. Then the leaves were dried in a dehydrator at 50 °C for 8 hr and ground using a Fritsch mill (with a 0.5 mm sieve). Finally, according to the ratio, spices were measured, added to a Hobart mixer, and

solids were homogeneously blended. The spice mixture was stored in an airtight container before use.

2.2.4 Preparation of vegetables

Pumpkin pieces were thoroughly washed and cleaned to remove dust and other foreign materials. The peel was removed. Thin slices of pumpkin were made (about 0.5 mm). They were steam-blanching for two minutes. Then the slices were spread over the trays and dried in a tunnel dryer at 60 °C for 8 hr (until moisture content was less than 10%). Finally, the dried slices were ground using a pin mill (with a 0.5 mm sieve). Pumpkin powder was stored in airtight containers separately.

Coconut milk powder was purchased at the local market. Centella leaves and spinach were specially treated to retain their green colour during processing. They were thoroughly washed and cleaned to remove the dust and other foreign materials. Spinach leaves were removed from their stems, Centella leaves were used with roots and stems, and they were immersed in a solution for five minutes (1% SMS, 1% MgCO₃, and 3% Citric acid solution, where the pH was maintained at 3.0 – 3.5) [11]. Then the leaves were spread over the trays and dried in a tunnel dryer at 55 °C for five hr, until moisture content was less than 10%, and ground using a Fritsch mill (with a 0.5 mm sieve).

Three formulations were prepared for the sensory evaluation by changing the ratio of the cereal mix. The amounts of soy and green gram flakes, spicy mix, pumpkin, Centella leaves, spinach, salt, coconut milk, water, and lime juice were set as fixed for the three formulas.

2.3 Nutritional Properties of Porridge

Moisture, ash, crude fat, dietary fiber, and crude protein content were determined according to AOAC official methods 925.10, 942.05, 923.03, 991.42, 923.04, respectively [1].

2.3.1 Mineral analysis

K, Ca, Fe, Mg, and Zn contents of the prepared porridge were measured using AAS, method 994.02 [1].

2.3.2 Vitamin analysis

2.3.2.1 β - Carotene content

β - Carotene content (Vitamin A) was determined according to the AOAC official method 2005.07, reversed-phase HPLC method [2].

2.3.2.2 Vitamin B complex

Vitamin B complex was determined according to the Vitamin Division, ROCHEL, Basel. ISBN 3-906507-00-9, [3]

2.4 Shelf-Life Analysis of Porridge

Shelf-life analysis was conducted using the best porridge formulation; the cereal pack was in double-laminated (LLDPE: PET) pouches, with vegetables and spices in double-laminated aluminum foils, and stored in a storage box at room temperature (27 ± 2 °C, RH: 74%). The sample was analysed with respect to the test parameters such as water activity, total plate count (TPC, SLS: 516: Part 1:

1991), and viable yeasts and mold count (Y & M, SLS 516: Part 2: 1991) for a period of 3 months [1], while drawing samples for the analysis monthly. All the tests were triplicated for each parameter.

2.5 Statistical Analysis

The results were expressed as mean $\pm$ standard error (SE) by comparing the means using one-way ANOVA in the IBM SPSS Statistics 22.0 package. Sensory scores were analysed using the Friedman test, followed by the Nemenyi post hoc test for mean separation when results were significant ($p < 0.05$).

3. Results

There were three main categories of ingredients in this porridge, including cereals, vegetables, and spices. Within the cereal category, two grains and two pulses were selected for this porridge. They were selected according to their nutritional value, use for porridge preparation in locally household level, sensory properties, and the locally availability. Two grains were selected: rice as the staple cereal and medeeri (Proso millet). According to the nutritional data, Proso millet contains the highest amount of Fe and vitamin A among the grains [8,10]. Pachchaperumal and Rathuheenati were selected as they contain the highest amounts of Fe and vitamin A among the traditional rice varieties [7]. When the whole rice was used, the cooking time for the rice was 30 minutes, and to reduce the cooking time without affecting the nutritional value, rice grits were made. Therefore, the cooking time of rice was reduced to 15 minutes.

Two pulses were selected: green gram and soybeans, due to their high caloric value and being the most abundant pulses in the country. They contain a high amount of anti-nutrients, so special processing (flaking) was done to minimize these anti-nutrients [8,10]. They were soaked for five hours, partially cooked over high flame for 15 minutes, and dried well before cooking the porridge.

In this porridge, pumpkin was used due to its high β -carotene content, and also Centella leaves (*Centella asiatica*) due to their high Fe content. Spinach leaves were selected as its high Fe content. Spinach contains a high amount of oxalic acid, which reduces the iron and calcium bioavailability. To increase the bioavailability of Fe, lime juice was added when the porridge reached room temperature. Vitamin C in lime juice increases the bioavailability of Fe.

The target energy value of the porridge is around 90 calories per serving [12]. To obtain that target energy value, using nutritional data, the required amount of ingredients was calculated, and several trials were conducted to get the correct texture, colour, and taste. Using the above ingredients, three types of porridge were prepared. The best ingredient combination was chosen by a sensory evaluation of the final three porridge samples.

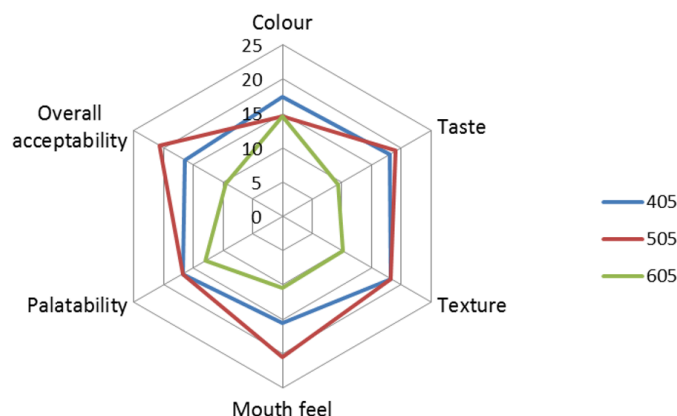


Fig. 1. Variations of sensory attributes of the porridge

According to Figure 1, the most preferable sample was sample 505. It has the highest sensory profile in every aspect except the colour. When compare the sample 405 and 505, 405 is of better quality in colour than 505, but has significantly low mouth feel and overall acceptability. With regard to taste, it shows slightly lower acceptability than 505, and the same level of acceptance was there for texture and palatability. For sample 605, except for colour, it shows a significantly lower sensory profile compared to samples 405 and 505.

Therefore, by processing the data obtained from the sensory evaluation of porridge, the formulation made using a 1:1 ratio between rice and medeeri obtained the highest sensory profile and thereby the highest consumer acceptability among the three samples and was selected for the nutritional analysis.

3.1. Proximate Analysis of Porridge

The nutritional composition of the prepared porridge for one serving (200 mL) was tabulated in Table 1

Table 1
Proximate values of the porridge

Parameter	Nutritional composition per 200 mL of porridge
Energy (Kcal)	78.525 (by calculation)
Protein (g)	3.171 ± 0.02
Fat (g)	3.925 ± 0.01
Total mineral (g)	1.942 ± 0.01
Dietary Fiber (g)	1.943 ± 0.01
Available carbohydrates(g)	7.629 ± 0.01

According to Table 1, a single serving of porridge contains a high amount of protein. This is due to porridge containing Proso millet, green gram, and soy, which are the protein-rich cereals available in the local market. Previous research on cereal–legume composite porridges has demonstrated that modifying the proportion of cereal and legume ingredients can significantly influence the proximate composition and nutrient density of the final product [9, 18]. One serving of the porridge contains a significantly high amount of fat due to the use of coconut milk and also soybean seeds. Dietary fiber content is also high in this porridge. Leafy vegetables contribute to the

higher portion of the dietary fiber content. Ash content indicates the amount of minerals present in the porridge. Ash content is reduced by processing methods like removal of the hull, dehulling, and minerals can be leached away during soaking, blanching, etc. A similar formulation approach was reported by Gamlath *et al.*, [6], who developed instant kola-kenda mixtures using rice, soybean, and leafy vegetables.

3.2 Mineral Content of Porridge

The mineral contents of the final product were tabulated in Table 2.

Table 2

Mineral content of the porridge per one serving

Mineral	Developed porridge/mg
Na	1106
Ca	16.4
Fe	6.4
Zn	1.2

According to Table 2, all the mineral levels showed a significant level that will affect the nutritional requirements of children. In the mineral content, the target mineral is iron in order to reduce anemia among the school children. The developed porridge contains a high amount of iron due to two rice varieties, which are high in Fe content in traditional rice varieties, along with green gram, Centella leaves, and spinach. Perera *et al.*, [11] also reported mean iron concentrations of 23.29, 29.56, and 45.16 mg/kg for cooked rice, green leaves, and pulses, respectively, among foods consumed by rural Sri Lankan schoolchildren.

3.3 Vitamin Content of Porridge

The vitamin contents of the porridge were tabulated in Table 3.

Table 3

Vitamin content of the porridge per one serving

Parameter	Developed porridge
β carotene	30.0 μ g
Vitamin B ₁	ND < 0.3 mg / 100 g
Vitamin B ₂	ND < 0.3 mg / 100 g
Vitamin B ₃	8.6 mg
Vitamin B ₆	0.4 mg
Vitamin B ₁₂	ND < 0.3 mg / 100 g

According to Table 3, the β -carotene level was 30.0 μ g, which is the precursor of vitamin A. Also, vitamin B3 and B6 were detected in the developed porridge. The aim of the development of this porridge is to increase the vitamin A content to prevent vitamin A deficiency. Pumpkin and Centella leaves contribute to the major part of the β -carotene level, and two rice varieties were also selected as the widest traditional varieties in β -carotene.

3.4 Storage Studies of Porridge

Grains and pulses contain comparatively higher moisture content and water activity than other vegetables and Spices. Also, they do not require specific barrier properties. Double-laminated transparent foils were used for the cereal packaging with a PET outer layer and a polyethylene inner layer. Pumpkin, Centella leaves, and spinach were dehydrated and absorb moisture quickly. Pumpkin contains a high amount of β -carotene, and it is affected by light. Also, the green colour of Centella leaves and spinach is affected by light. Spices require an aroma barrier property. Therefore, that double laminated aluminum foils were used for the vegetable packaging, with a metal outer layer and a polyethylene inner layer. Then the two packets were packed in polyethylene as the final pack. Shelf life was analyzed in terms of changes in moisture content, water activity, and free fatty acid level during the storage period of 3 months.

Moisture content of the porridge was kept nearly constant ($p>0.05$) during the period of three months of storage. Water activity of the porridge changed slightly during the period of three months of storage (Cereal pack: 0.495 – 0.5; Aluminium pack: 0.398 – 0.410), but the increment was not significant ($p>0.05$). Acid value was not obtained for both packets for three months period, which indicates that there was no hydrolysis of triglycerides during this period. According to the microbial analysis, total plate count and viable yeast and mold count were much lower values in both packages than the standard values (TPC; $<1 \times 10^4$; Y&M; $<1 \times 10^2$).

4. Conclusions

During this study, the caloric value of the porridge was implemented while increasing the vitamin A and iron content to prevent major micronutrient deficiencies among school children. The nutritional composition of the porridge revealed that the caloric value, protein, fat, dietary fiber, available carbohydrate, and ash content of the final product (per one serving, 200 mL) were 78.525 Kcal, 3.171 g, 3.925 g, 1.943 g, 7.629 g, 1.942 g, respectively. The final product contained 1.1 g, 16.4 mg, 6.4 mg, and 1.2 mg of Na, Ca, Fe, and Zn, respectively. Also, it contained 30.0 μ g, 8.6 mg, and 0.4 mg of β -carotene, Vitamin B3, and Vitamin B6. According to the storage studies, the developed dry formula can be stored under normal atmospheric conditions (27 ± 2 °C, RH: 74%) for three months. These findings suggest that the developed porridge formula can serve as a child-friendly breakfast item that meets a 1/4th proportion of toddlers' daily energy needs from locally available grains, vegetables, and spices. Moreover, this product can promote local grains and pulses while providing healthy calorie intake along with vitamin A and iron for children, addressing both nutritional and economic aspects of child malnutrition in developing countries.

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