Development of a Low Cost Yoghurt Based Weaning Food for 1-3 Years old Toddlers by Incorporation of Mung bean (*Vigna radiata*), Soy bean (*Glycine max*) and Brown Rice (*Oryza sativa*) for the Sri Lankan Market

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Abstract

Three extruded weaning foods were formulated at different ratios blending of brown rice (*Oryza sativa*), soybean (*Glycine max*), mung bean (*Vigna radiata*) and milk powder blend with yoghurt (fermented with starter culture containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus*) to achieve the recommended level of nutrients for a toddler aged between 1-3 years. These three formulated products were compared with a commercially available weaning food. Chemical, physical, microbiological and shelf life evaluations were conducted separately for each four weaning foods. Protein, fat, energy, dry matter, ash and water solubility index of formulated weaning foods were found to be significantly (*P*<0.05) higher than the levels in commercial WF. Moisture, carbohydrate and water binding capacity were significantly (*P*<0.05) lower than the levels in commercial WF. The microbial counts of both flour and yoghurt separately, and for the gruel form were within the limits of recommendations. There were no significant difference (*P*>0.05) between the moisture contents before and after 21 days of storage for flours which implied those were stable after 21 days. Titratable acidity and pH indicated that the yoghurt was stable until16 days. In the sensory evaluation for the appearance, aroma, taste, mouth feel and overall acceptability highest mean scores and sums of ranks were achieved by formulated weaning foods than the commercial one. According to the overall chemical and sensory evaluation results weaning food-2 (Rice-2%, mung bean, 17%, soybean-3%, milk-3%, yoghurt-75%) was selected as the best one. Fifty one percentage of profit can be achieved by producing these low cost diets than the commercial diet.

Key words: extrusion, low cost, sensory, toddler

1. Introduction

Malnutrition has become one of the major health problems facing by developing countries. Throughout the developing world, malnutrition affects 800 million people, or 20 percent of the world population (USAID, 2002; WHO, 2000). The total number of malnourished children in the world between age group 0-4 years reported to be around 100 million. Around 6,600,000 children (0-4 years old) are suffering from severe malnutrition and 64 million children (0-4 years old) are suffering from moderate malnourishment in Asia (Rechcigl, 1982). Malnutrition in Sri Lanka continues to prevail relatively at higher levels. Sri Lankan demographic and health survey (2006-2007)
highlights that 18%, 15%, 22% and 4% of Sri Lankan children are stunted, wasted, underweighted and severely underweighted, respectively (Annual report, 2008).

Malnutrition can be defined as inadequate or excess intake of macro and micro nutrients. Protein Energy Malnutrition (PEM) occurs during the transitional phase when children are weaned from liquid to semi-solid or fully adult foods. Moreover, iron deficiency is the most prevalent micronutrient disorder worldwide (WHO, 2000). The United Nations Administrative Committee on Coordination/ Subcommittee on nutrition (ACC/SCN) estimates that as many as 3.5 billion people in the developing world may be affected by the iron deficiency. Asia has the highest prevalence of anemia, the most serious form of iron deficiency (ACC/SCN, 2001). Women at reproductive stage and children are severely affected. High price of commercially available weaning foods, vegetables, animal proteins and the non-availability of low priced nutritious foods, combined with bad feeding practices and late introduction of supplementary foods, are mostly responsible for this malnourishment among children (Suite, 2007).

The global public health recommendation is to breastfeed the infants for the first six months of their life in order to achieve an optimal growth and development followed by providing complementary feed according to the nutritional requirement of the child with the continuation of breastfeeding until 2 years of age. Weaning is the process of complete transition from a breast feeding to a semi solid diet for the infants. Weaning foods are generally introduced between the ages of six months to three years old as breastfeeding is discontinued. The minimum predicted age for a natural weaning in humans is about 2.5 years, with a maximum of 7.0 years. During weaning, both macro and micro nutrients will be insufficient and therefore, protein energy malnutrition and micronutrient deficiency can occur together. Abrupt weaning where the infant is straightly introduced into the family menu also causes malnutrition, growth retardation, infection, and higher rates of mortality (Suite, 2007). Toddler is a young child between the ages of one and three. Though the growth rate is lower than the infancy, a toddler needs a high nutritional demand for growth and development. Due to the increased activity, a toddler needs a high energy requirement. According to recommendations, a toddler requires energy intake of 5358.76 kJ/day (1282 kcal/day), and 15.52 g/day, 210 g/day and 44 g/day of protein, carbohydrate and fat intake, respectively. Good nutrition during infancy and childhood can promote adequate physical and mental development. Some of the published researches have been showed that most of the weaning foods consumed in developing nations are deficient in essential nutrients, especially protein (FAO/WHO, 1998). Most of the weaning foods are lack in proteins since they are based on cereals (maize, millet, sorghum) which are a poor source of protein. Several strategies have been used to improve the nutritive value of weaning foods (Harper & Jansen, 1985) namely, malting, dry roasting, milling, steaming, boiling, and sprouting which are some simple processes being used in the production of weaning foods (Wikramanayaka, 1996).

Food based approaches used in combination with nutrition education programs can be used as a strategy to fight against the nutrient deficiencies.
One such strategy is to incorporate legumes with cereals. Therefore, locally available legumes: mung bean (*Vigna radiata*) and soy bean (*Glycine max*) can be used due to their high protein and iron content. Moreover, these two legumes have been popularized in the South Asian diets since from a long period of time. As these cereals are relatively low cost source of iron and protein, they can be used to prepare supplementary foods for children in low income families (Vijayalakshmi et al., 2003). Legumes are high in lysine but lack in sulfur-containing amino acids. On the other hand, cereals are lack in lysine but high in sulfur-containing amino acids. Hence, incorporation of legumes with cereals is advantageous in blending of these beneficial nutritional characteristics. Moreover, soy bean contains zero cholesterol with high amount of healthy unsaturated fatty acids which could impact greatly on health.

Low cost extrusion cooking is a food processing technology that rapidly mixes and cooks the feed material at temperatures of over 100 °C and dry the product in a relatively short time. This thermal process improves the nutritional quality of raw food material and eliminates vegetative microorganisms. Extruded products can be fortified with vitamin and minerals. This process can be used to produce product in large scale for the developing countries (Bangoru & Zhou, 2007). Fermentation is one of the oldest methods practiced by human beings for the transformation of milk into products with an extended shelf life. One of the most popular fermented milks is known in Bulgaria and Turkey as yoghurt or yogurt; it is also known as matzoon in the USA and as leben in Egypt (Johnson, 1987). Yoghurt is a firm, creamy or liquid acidified milk product manufactured from pasteurized milk using thermophilic lactic acid bacteria (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*). There are many types of yoghurt available in the world such as set yoghurt, stirred yoghurt, drinking yoghurt, frozen yoghurt, concentrated yoghurt, and flavored yoghurt (Johnson, 1987). Yoghurt is popular worldwide due to its health benefits as a functional food in addition to its nutritional benefits. As the milk proteins, fat, and lactose components undergo partial hydrolysis during fermentation, yoghurt is an easily digested product of milk (Rabinson & Tamime, 1985). Probiotic yoghurt (with certain specific strains of *Lactobacillus* and *Bifidobacter*) is known to relieve intestinal discomfort, prevent diarrhea and improve recovery (Korpela et al., 2003). In addition, yoghurt is a good solution for people with lactose intolerance. Therefore incorporation of yoghurt into the children diet is an added advantage.

Though many infant formulas are available in the market, there is a problem whether those are fulfilling the child requirement with optimum safety and whether they are affordable for the low income families where malnutrition occurs. Hence, this study was an exploratory work to formulate energy and nutritional rich, low cost composite blend, based on locally available cereals such as rice, and legumes such as soybean and mung bean by blending with yoghurt to produce a highly nutritious low cost weaning food to reduce the malnourishment of Sri Lankan children. Therefore, the objective of the current study was to formulate a yoghurt-based weaning food for toddlers by blending rice, mung beans and soy
beans which provide the recommended nutritional requirements.

2. Methods
Rice (Oryza sativa), green gram (Vigna radiata), soy bean (Glycine max), cocoa powder and full cream milk powder were purchased from the local market.

2.1 Preparation of the ingredients
2.1.1 Preparation of green gram
The green gram was sorted, cleaned and washed with clean water to eliminate any dirt, damaged grains and inert matter, and soaked in water for 8 h. After draining of water, they were dried at 50 ºC for 24 h. Then they were roasted under an open flame (160 ºC) until become golden brown, cooled and partially milled using a Ferrell-Ross® roller mill (Ferrell-Ross Corp, Oklanoma city, Okla, USA) to reduce grain size.

2.1.2 Preparation of rice
Brown rice was prepared according to the method previously described by Bangoru & Zhaou (2007). Grains were dried in a dehydrator at 55 ºC for 1 h and partially milled using a Ferrell-Ross® roller mill (Ferrell-Ross Corp, Oklanoma city, Okla, USA).

2.1.3 Preparation of soy bean
Grains were soaked for 8 h and drained out for 1 h by placing on a nylon sieve. Then grains were dried at 50 ºC for 24 h, roasted under an open flame (160 ºC) until become golden brown coloured, de-hulled using a Bauer 148-2 de-huller (Bauer bros.co, USA) and partially milled using a Ferrell-Ross® roller mill (Ferrell-Ross Corp, Oklanoma city, Okla, USA).

2.1.4 Preparation of Set Yoghurt
Cow milk obtained from Mawela farm, University of Peradeniya, Sri Lanka. Milk was standardized with cream in order to obtain a final fat content of 4%. Standardized milk was heated to 60 ºC and homogenized. Then sugar and gelatin were added and the mix was pasteurized (95 ºC for 5 min). Then the mix was cooled to 45 ºC and the starter culture containing Streptococcus thermophilus and Lactobacillus bulgaricus was added at the rate of 2% (w/v). The mix was incubated in an ACP incubator (ACP Co Ltd, Japan) at 42-45 ºC 2 h. Incubation was terminated at pH 4.6 and stored under refrigerated conditions until use.

2.2 Treatments and Formulation
Trial and error method was used to formulate three weaning foods (WF1, WF2 and WF3) that meet the nutrient requirement of toddlers according to the recommendations of the World Health Organization. A 100 g portion of each of these mixtures was formulated to provide one third of daily energy and carbohydrate requirement, two third of daily protein requirement and one fourth of daily fat requirement for a growing toddler. The ingredient ratios were estimated using nutrient and caloric values of each ingredient (Table 1). After the flour and yoghurt ratios of three weaning foods have been determined, the next step was to calculate the amount of each ingredient which was used to formulate the flour mixture. Prepared mung bean, soy bean and rice were blended according to the relevant proportions as stated in the Table 2. Each blend was extruded separately using a co-rotating twin screw extruder (die size 0.25 inches) with a smooth barrel. The resulted extruded products were milled into flour using a Fitz® 832D Fitz mill.
(The Fitzpatrick Company, Russia) and sieved through a 0.3 mm sieve. There after 3% spray dried milk powder and 5% coco powder were added to each blend. Then the composite flour mixtures of each treatment were mixed with corresponding yoghurt volume as in the Table 2 in order to make slurry which served for the sensory evaluation. Three formulated weaning foods (WF1, WF2 and WF3) were compared with a commercially available weaning food which assigned into 4 treatments as T1, T2, T3 and T4, respectively. The composition of the four treatments has been illustrated in the Table 2.

**Table 1:** The nutrient content of raw materials used for infant formula

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Nutrient content (g/100 g raw material)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy</td>
</tr>
<tr>
<td>Brown rice</td>
<td>1503 kJ(359 kcal)</td>
</tr>
<tr>
<td>Soy bean</td>
<td>1758 kJ(420 kcal)</td>
</tr>
<tr>
<td>Mung bean</td>
<td>1398 kJ(334 kcal)</td>
</tr>
<tr>
<td>Milk powder</td>
<td>2080 kJ(500 kcal)</td>
</tr>
</tbody>
</table>

*Source: (Wikramanayaka, 1996)*

**2.3 Sensory evaluation of formulated diets using untrained panelist**

Fifty grams of each weaning food was made into paste and presented for sensory evaluation for thirty untrained panelists. The attributes concerned were appearance, aroma, taste, mouth feel, color and overall acceptability. The panelists were asked to assign score according to their preference for the various attributes using a seven (7) point hedonic scale where 1 for extremely dislike and 7 for extremely like. The samples presented to the panelists were displayed in the Table 2.

As indicated above, for the comparison commercial weaning food was formulated to obtain total content of 100 g based on its recommendations. Table 3 shows the nutrient content supplied by the commercial weaning food according to its recommendations in order to supply nutrient requirement for a day of a 1-3 year child.

**Table 2:** Compositions of the Treatments used for the sensory evaluation

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>T1(g)</th>
<th>T2(g)</th>
<th>T3(g)</th>
<th>T4 Commercial weaning food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown rice</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>14.28g weaning food powder with 85.71 ml liquid milk*</td>
</tr>
<tr>
<td>Mung bean</td>
<td>11</td>
<td>17</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Soy bean</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Dried milk powder</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Yoghurt</td>
<td>80</td>
<td>75</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Nutrients supplied by the commercial weaning food according to its recommendations (All values are expressed in dry weight basis)

<table>
<thead>
<tr>
<th>Weaning food</th>
<th>Crude Protein %</th>
<th>Dry Matter %</th>
<th>Crude Fiber %</th>
<th>Crude Fat %</th>
<th>CHO %</th>
<th>Ash %</th>
<th>Caloric Value(kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Weaning food*</td>
<td>13.80</td>
<td>38.64</td>
<td>1.00</td>
<td>10.40</td>
<td>73.59</td>
<td>1.21</td>
<td>399.50</td>
</tr>
</tbody>
</table>

*25 g of weaning food powder was dissolved in 150 mL liquid milk

2.4 Analysis of nutritional quality, physical quality, microbiological quality and shelf life

The developed three weaning foods and the commercially available weaning food were analyzed for nutritional, physical, microbiological and sensory properties. Experiments were conducted in triplicate.

2.4.1 Nutritional analysis

The moisture, dry matter, ash, crude protein, crude fat, carbohydrate and crude fiber content of the four treatments were analyzed by proximate composition analysis as described in the AOAC protocols (1995).

2.4.2 Physical Properties

The water binding capacity and water solubility index were determined according to the methods previously described by Castell-Perez and Griffith (1998). Energy conversion factors were used in calculating the caloric value of the nutrients (Bangoru and Zhou, 2007).

2.4.3 Evaluation of Shelf life

Since this weaning food will be marketed in two separate parts: one for yoghurt mixture and the other for grain mixture, however in the same container, the shelf life was determined separately for the flour mixture and yoghurt. Moisture content in the flour mixture was determined at 7 day intervals until 21 days of storage according to the method previously described by Amankwak et al. (2009); whereas, the pH and Titratable acidity were determined for the yoghurt 4 days interval during storage at 4 ºC with two replicates for 28 days. Nine milliliters of the sample was taken into 100 ml Erlen Mayer Flask and 1 ml of 1% phenolphalein solution was added into it. Then the sample was titrated with 0.1 N NaOH until a permanent pale pink color was observed and the burette reading (V) was recorded in order to determine the Titratable acidity (%) according to the following Equation 1.

\[ \text{Titratable acidity} \% (\text{w/v}) = \frac{V}{10} \]  

\[ \text{pH} \text{ was measured using the Hannah 211 electric pH meter (Hannah Corp, Mauritius).} \]

2.5 Microbiological Analysis

The microbiological analysis was conducted separately for the grain mixture, yoghurt and for the freshly prepared gruel form (mixed with yoghurt).

2.5.1 Coliform count for yoghurt
Test was done for the minus one dilution and without any dilution (direct). For the direct pouring point one milliliter from each sample was transferred into sterile petri-dish which was kept in a Heraeus T 5042 K drying oven (Tamson, Zoetermeer, Holland) for 2 h. Point one milliliters (0.1 mL) from 10⁻¹ dilution series was poured into another petri-dish for checking the coliform count for 10⁻¹ dilution of the sample. Then 12 mL of Violet Red Bile (VRB) agar 48 ± 1 °C was poured into each Petri-dish followed by mixing the content by rotating the closed Petri-dishes. The agar was then allowed to solidify at room temperature (27 °C). The plates were incubated in an inverted position aerobically at 30 ± 1 °C for 24 h in a Fisher 322 incubator (Scientific Company, USA). The colonies were counted manually and the results were expressed as Colony Forming Units (C.F.U) per gram. Colonies were identified as enumerate blue and red colonies associated with entrapped gas regardless of size or intensity of color (Joseph, 2009).

2.5.2 Coliform count and total viable count/standard plate count/aerobic plate count for Flour mixture

Coliform count in the flour mixture was determined according to the same procedure as described in the section 2.5.1. Total viable plate count was determined for the dilution series from 10⁻¹ to 10⁶. Nevertheless, 10⁻¹ dilution was made from 0.1 g of each sample dissolved in 0.9 mL of distilled water. Moreover, 10⁻² dilution was made from dissolving 0.1 mL from 10⁻¹ dilution in a 0.9 mL of distilled water and other dilution levels were made according to the same procedure. Then 0.1 mL from each dilution was poured into Petri-dish containing 12 mL of plate count agar at 48 ± 1 °C followed by mixing the content by rotating the closed Petri-dishes. The agar was then allowed to solidify at room temperature (27 °C). The plates were incubated in an inverted position at 37 °C for 48 h in a Fisher 322 incubator (Scientific Company, USA). The colonies were counted manually and the results were expressed as the number of Colony Forming Units (C.F.U) per gram.

2.6 Statistical analysis

Statistical analysis was carried out using Complete Randomized Design (CRD) with SAS version 9.0, and determinations were done in triplicate. Least significant difference (LSD) mean separation procedure of the SAS computer package was used to obtain the mean separation of the results obtained. Statistical analysis of the sensory evaluation data were carried out using, Friedman non parametric procedure in Minitab. Any significant differences were determined at \( P < 0.05 \) level.

3. Results and Discussion

3.1 Nutritional composition of the weaning foods

The proximate composition of the four treatments is stated in the Table 4. The proximate analysis was used to determine overall nutritional content of the formulated diets.

3.1.1 Protein content

Mung bean and soy bean were used as the main plant protein source while yoghurt was used as the main animal protein source. The protein content of formulated weaning foods were higher than \( P < 0.05 \) the levels in commercial weaning food. These results were similar to those reported
by Bangoru and Zhou (2007). The protein content of WF1, WF2 and WF3 were approximately five times higher than that of the WF4 (commercial product) where the mean values ranged from 16.28 to 03.77 (% DM). The recommended amount of the commercial weaning food also provides less protein content than the prepared formulations (WF1, 2, and 3). This higher protein content could be due to the processing technique used to prepare the weaning foods such as roasting which helped in the breakdown of lipocytes to release fat and protein (Wikramanayaka, 1996). Roasting improved sensory qualities and aided in inactivation of destructive enzymes, which improves the storage and nutritional quality of the product and reduce trypsin inhibitor activity when seed temperatures reached 90–100 °C where the lipoxygenase activity loss at temperatures of 75–80 °C (Castell-Perez and Griffit, 1998). According to FAO/WHO (1982) a minimum protein content of 15% is required for maximum complementation of amino acids in foods and growth, thus all these three formulations were satisfied the protein demand of 1-3 year old children. According to Wickramanayaka (1996) the high lysine content of legumes improve the nutritional quality of cereals by complementing the limiting amino acids. Sulphur containing amino acids such as methionine are limiting in legumes and relatively high in cereals whereas lysine is limiting in cereals and high in legumes.

**Table 4**: Proximate composition and energy content of supplementary diets (Dry weight basis) (WF = Weaning Food)

<table>
<thead>
<tr>
<th>Nutrient (%)</th>
<th>WF1</th>
<th>WF2</th>
<th>WF3</th>
<th>WF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>15.22±</td>
<td>16.28±</td>
<td>16.19±</td>
<td>03.77±</td>
</tr>
<tr>
<td>Moisture</td>
<td>56.42±</td>
<td>53.53±</td>
<td>50.75±</td>
<td>77.42±</td>
</tr>
<tr>
<td>Dry matter</td>
<td>42.53±</td>
<td>42.53±</td>
<td>50.18±</td>
<td>24.57±</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>0.71±0</td>
<td>0.93±0</td>
<td>0.81±0</td>
<td>0.54±0</td>
</tr>
<tr>
<td>Crude fat</td>
<td>12.43±</td>
<td>12.38±</td>
<td>12.38±</td>
<td>02.70±</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>69.07±</td>
<td>68.55±</td>
<td>68.10±</td>
<td>92.25±</td>
</tr>
<tr>
<td>Ash</td>
<td>1.70±0</td>
<td>1.69±0</td>
<td>1.66±0</td>
<td>1.04±0</td>
</tr>
<tr>
<td>Energy</td>
<td>1854.3</td>
<td>1845.0</td>
<td>1835.9</td>
<td>1612.5</td>
</tr>
</tbody>
</table>

Note: All values in the same column with different superscripts are significantly different at (P < 0.05)

**3.1.2 Moisture Content**

The moisture content of formulated weaning foods (gruel form) were significantly (P < 0.05) lower than the levels in commercial weaning food. The moisture content values were ranged from 56.42 to 77.42 % where the commercial product has shown the highest mean moisture content. Perhaps this could be due to its high water binding capacity. As this product is marketed as two separated portions of flour and yoghurt (in one container), moisture content was determined separately other than the finally prepared paste.

**Table 5**: Moisture content of the weaning food flour mixtures and yoghurt

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>6±1.20</th>
<th>8±0.41</th>
<th>9±0.61</th>
<th>1±0.38</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>ab</td>
<td>b</td>
<td>c</td>
<td></td>
</tr>
</tbody>
</table>

Note: All values in the same column with different superscripts are significantly different at (P < 0.05)
Nelson (1992) has reported that moisture content is used as a quality factor for prepared cereals which should have 3-8% moisture content. The moisture content of formulated weaning food flour mixtures were significantly ($P < 0.05$) higher than the levels in commercial weaning food. But they were within the acceptable range with low mean moisture contents which meet the recommendations of Protein Advisory Group (PAG, 1971) guidelines for weaning foods. Moisture should be between 5 to 10% and they are required for convenient packaging and transport of products (Oduro et al., 2007).

### 3.1.3 Dry Matter Content

The dry matter content of formulated weaning foods (gruel form) were significantly ($P < 0.05$) higher than the levels in commercial weaning food. The dry matter content values were ranged from 24.57 to 50.18% where the WF3 showed the highest mean dry matter content. The dry matter content higher means overall nutritional content is also high.

### 3.1.4 Crude Fat Content

The crude fat content of formulated weaning foods were significantly ($P < 0.05$) higher than the levels in commercial weaning food. The crude fat content of formulated weaning foods was able to supply one forth of daily fat requirement of a 1-3 year old toddler where recommended amount of commercial food supplies only one eighth of the fat requirement. The fat content of a food sample can affect its shelf stability. This is because fat can undergo oxidative deterioration, which leads to rancidification and spoilage. Hence a food sample with high fat content is more liable to spoilage than one with a lower fat content (Amankwah et al., 2009). Protein Advisory group (PAG, 1971) recommends fat content of a weaning food should be not more than 10% due to oxidative deterioration. But in the formulated diets as yoghurt and flour mixture keep separately total fat content of 12% will not affect for its shelf life. In the current study, soybean and yoghurt were used as the main fat suppliers. Soybean oil agree with the recommendations of (FAO/WHO, 1998) that vegetable oils can be included in foods meant for infants and children, which will not only increase the energy density, but also be a carrier for fat soluble vitamins and provide essential fatty acids. Soybean and cereals contain unsaturated fats (Wikramanayaka, 1996) which does not increase the cholesterol in the blood hence can be recommended for children.

### 3.1.5 Ash Content

WF1 gave the highest mean value for the ash%. The ash content of formulated weaning foods were significantly ($P < 0.05$) higher than the levels in commercial weaning food. But ash contents were the same ($P > 0.05$) between the formulated diets. The ash content of the products indicates the mineral content of the products. Acceptable ash content of weaning foods which given by the
Protein Advisory Group (1972) should not exceed 5%. Formulated foods studied in the current study were within this limit.

3.1.6 Crude Fiber Content
The lowest mean value for crude fiber content was observed in WF4. The crude fiber content of formulated weaning foods were significantly ($P < 0.05$) higher than the levels in commercial weaning food. Acceptable fiber content of weaning foods should not exceed 5% (PAG, 1972) and formulated foods were within this limit because when fiber content is high it decreases the digestibility of the food. The dietary fiber fractions of all weaning foods were comparatively low due to the incorporation of de-hulled legumes (Ghasemzadeh and Ghavide, 2011).

3.1.7 Analysis of carbohydrate content
The carbohydrate content of formulated weaning foods were significantly ($P<0.05$) lower than the levels in commercial weaning food. The commercial product has shown the highest mean CHO content and this is because of its lower crude protein and crude fat contents. All these three formulated weaning foods were able to supply one third of daily carbohydrate requirement of a 1-3 years old toddler. In this study brown rice was used as the main carbohydrate supplier which helped to maintain the carbohydrate content over 65% as the recommendations made by PGA (1971).

3.2 Physical Property Analysis

3.2.1 Caloric Content
Table 6 shows the caloric values of each nutrient in different weaning foods which evaluated in the current research study. Calories in a diet is provided by protein, fat and carbohydrates (Wikramanayaka, 1996). The calorie content of formulated weaning foods were significantly ($P<0.05$) higher than the levels in commercial weaning food. These results were similar to those reported by (Bangoru and Zhou, 2007). The values were ranged from 385.77 to 443.63. Weaning foods were provided protein caloric content ranges from 16.58 to 68.37 respectively and provided 4.19% to 26.69% of energy content. The fat caloric content of formulations was ranges from 26.8467 to 118.5133 and representing 6.92 % to 26.69% energy content. Carbohydrate caloric content was determined as 257.3267 to 343.6300 and provided 58.31% to 88.87% of energy content. The carbohydrate caloric a content of commercial weaning food was slightly higher than the Protein Advisory Group (1972) values of 50-60% due to higher carbohydrate content and formulated foods were within the acceptable range. Protein caloric content of formulated diets were in acceptable range of 10%-20% and also in the acceptable range of fat caloric content which is below 30% recommended by Protein Advisory Group (1972). This indicates that formulated weaning foods were supplied one third of needed energy per day of a 1-3 years old toddler.

3.2.2 Water Binding Capacity (WBC)
The WBC of formulated weaning foods were significantly ($P<0.05$) lower than the levels in commercial weaning food. The values were ranged from 1.67 to 3.28 (Table 7). The high fat, high protein, low carbohydrate content of weaning food corresponds to the reduced WBC observed (Castell-Perez and Griffit, 1998). When starch content is high as in commercial weaning
food then the water binding capacity also high because starch absorbs more water. Lower absorption capacity is desirable for making thinner gruels (Ghasemzadeh and Ghavide, 2011).

### 3.2.3 Water Solubility Index (WSI)

The WSI of formulated weaning foods were significantly \((P<0.05)\) higher than the levels in commercial weaning food. The values were ranged from 12.45 to 30.28 (Table 7). WAI and WSI assumed an inverse relationship \((r = -0.916)\). When water solubility is high it will make a fine paste and improve the mouth feel. Sugar and milk powder can be added to increase the WSI. The extruded products usually increase the water solubility because, cooking increase the susceptibility of grain starch to glucoamylase hydrolysis indicating that starch was gelatinized during processing (Castell-Perez and Griffit, 1998).

**Table 6:** Caloric values supply by each nutrient as ingredient in different weaning foods

<table>
<thead>
<tr>
<th>WF</th>
<th>Caloric value (kcal)</th>
<th>Protein caloric content(kcal)</th>
<th>Fat caloric content(kcal)</th>
<th>CHO caloric content(kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF1</td>
<td>443.63(^a) (1854.36(^a) kJ)</td>
<td>65.65(^b)</td>
<td>118.51(^a)</td>
<td>259.64(^b)</td>
</tr>
<tr>
<td>WF2</td>
<td>441.41(^ab) (1845.08(^ab) kJ)</td>
<td>65.65(^b)</td>
<td>117.00(^a)</td>
<td>257.33(^c)</td>
</tr>
<tr>
<td>WF3</td>
<td>439.23(^b) (1835.99(^b) kJ)</td>
<td>68.37(^a)</td>
<td>113.12(^b)</td>
<td>257.86(^c)</td>
</tr>
<tr>
<td>WF4</td>
<td>385.77(^c) (1612.51(^c) kJ)</td>
<td>16.58(^c)</td>
<td>026.85(^c)</td>
<td>34363(^a)</td>
</tr>
</tbody>
</table>

Note: All values in the same column with different superscripts are significantly different at \((P<0.05)\)

### 3.3 Microbiological analysis

Microbiological analysis was conducted for the gruel prepared by blending yoghurt and flour mixture and for the flour mixture and yoghurt separately to determine their wholesome for consumption. According to Sri Lankan Standards (SLS) (1989) for the yoghurt, acceptable coli form count is <1 CFU/g. Hence Coli form counts of both flour mixtures and yoghurt were in acceptable range (Table 8). According to the recommendations of UK Food Protection Agency and Food Standards Australia New Zealand (FSANZ) acceptable Total Plate Count (TPC) for cereal flour mixtures is <10\(^7\) CFU/g and coliform...
count is $<3$ CFU/g and formulated weaning foods were in that acceptable range. The spoilage of many foods may be imminent when the total viable count reaches 10-100 million per gram of product.

Moreover, the TPC and coliform counts of each treatment in gruel form are displayed in the Table 9. According to recommendations of UK Food Protection Agency and Food Standards Australia New Zealand (FSANZ) acceptable Total Plate Count (TPC) for ready to eat food items is $<10^5$ CFU/g and coliform count is $<3$ CFU/g. Formulated weaning foods were in that acceptable range and wholesome to consume.

3.4. Determination of Shelf Life

3.4.1. Variation in Moisture Content during the Storage

The diets were packaged in triple laminated Aluminum foil. After 21 days with 7 days interval moisture content of the diets were determined to find out if the packaging material could serve as a good barrier between diets and environment. Figure 1 illustrates the variation in moisture content over the experimental period with regard to the treatments. The moisture content in WF1 increased from 4.85% to 5.82% for 21 days. In WF2, it was increased from 4.96% to 6.78% and in WF3 increased from 4.8% to 5.87 and in FW4 from 2.42% to FW 3.89%. The change in moisture content may be due to the ineffective sealing of the packaged products; hence air movement and moisture were increased. The resulting moisture contents of all formulations were fallen within the moisture content of 3-8% recommended by (PAG, 1971). Moisture contents were same ($P>0.05$) before and after 21 days and that implied the formulations were stable even after 21 days of formulation. The products will have longer shelf life if stored at low temperatures, due to slow air movement and low moisture diffusion coefficient (Amankwah et al., 2009).

3.4.2 Variation pH during the Storage

The variation in pH of the yoghurt has been illustrated in the Figure 2 which was measured at 4 days interval over 28 days. pH value was declined throughout the storage period of the yoghurt. pH value of the replicate one varies from 4.62 to 4.31 and 4.58 to 4.29 and 4.64 to 4.28 in the replicate 2 and 3, respectively. On the 20\textsuperscript{th} day, sour taste and unpleasant odor were observed and therefore, yoghurt was not suitable for the consumption. Hence, shelf life of the yoghurt was determined as 16 days.

3.4.3 Variation in Titratable Acidity during the Storage

The variation in the Titratable acidity of the yoghurt (3 replicates) which was measured at 4 days interval over 28 days has been illustrated in the Figure 3. Titratable acidity was increased throughout the storage period of the yoghurt. The highest change was observed in the replicate 1. These values were within the recommended range of titratable acidity of yoghurt which is 0.8-1.25% according to the SLS (1989). Therefore, the shelf life of the yoghurt was confirmed as 16 days by considering the pH value also.
Table 8: Microbiological analysis for the weaning food flour mixtures and yoghurt separately

<table>
<thead>
<tr>
<th>Component of weaning food</th>
<th>TPC (CFU/g) x (10^6)</th>
<th>Coliform count (CFU/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF1 flour mixture</td>
<td>2.80</td>
<td>0</td>
</tr>
<tr>
<td>WF2 flour mixture</td>
<td>2.75</td>
<td>0</td>
</tr>
<tr>
<td>WF3 flour mixture</td>
<td>3.20</td>
<td>0</td>
</tr>
<tr>
<td>WF4 flour mixture</td>
<td>2.45</td>
<td>0</td>
</tr>
<tr>
<td>Yoghurt</td>
<td>ND</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: ND = not determined

Table 9: Microbiological analysis of weaning foods in gruel form

<table>
<thead>
<tr>
<th>Weaning food in gruel form (fresh sample)</th>
<th>TPC (CFU/g) x (10^4)</th>
<th>Coliform count (CFU/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF1</td>
<td>5.94</td>
<td>0</td>
</tr>
<tr>
<td>WF2</td>
<td>5.62</td>
<td>0</td>
</tr>
<tr>
<td>WF3</td>
<td>6.34</td>
<td>0</td>
</tr>
<tr>
<td>WF4</td>
<td>5.79</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: WF= Weaning Food

Figure 1: Change in the moisture content of different treatment with time over the experimental period
3.5 Sensory evaluation

The estimated sums of ranks for the tested sensory attributes (appearance, aroma, taste, colour and overall acceptability) of for the treatments are mentioned in the Table 10.

3.5.1 Appearance
Since the adjusted probability value was less than 0.05, there was a significant different at least between two samples. According to the results the highest median value and the sums of ranks were obtained for the appearance of the WF2. It may be due to the ratio of 3:1 yoghurt: flour mixture which made fine slurry than the other treatments.

\[
S = 15.21, \text{ DF} = 3, \text{ P} = 0.002
\]
\[
S = 16.90, \text{ DF} = 3, \text{ P} = 0.001 \text{ (adjusted for ties)}
\]
\[
\text{Grand median} = 2.7500
\]

3.5.2 Aroma
Because the adjusted probability value was higher than 0.05, there was no significant different between aroma of samples.

\[
S = 3.28, \text{ DF} = 3, \text{ P} = 0.350
\]

3.5.3 Taste
Because the adjusted probability value was less than 0.05, there was a significant different at least between two samples. According to the results the highest median value and the sums of ranks were obtained for the taste in the weaning food2. Hence it can be interpreted that WF2 gives better taste than other samples. This may be due to higher fat and protein content of weaning food2.

\[
S = 23.08, \text{ DF} = 3, \text{ P} = 0.000
\]
\[
S = 26.43, \text{ DF} = 3, \text{ P} = 0.000 \text{ (adjusted for ties)}
\]
\[
\text{Grand median} = 2.625
\]

3.5.4 Mouth feel
Because the adjusted probability value was less than 0.05, there was a significant different at least between two samples. According to the results WF1, WF2 and WF3 were given higher median values and the sums of ranks for mouth feel. Hence it can be interpreted that WF1, WF2 and WF3 were given better mouth feel than other samples. This is because the particle sizes of
weaning food prepared in study was fine thereby texture of the weaning food also observed to be fine. WF2 got the highest rank due to fine paste it made with 3:1 yoghurt: flour mixture. 
S = 10.51, DF = 3, P = 0.015  
S = 11.76, DF = 3, P = 0.008 (adjusted for ties)  
Grand median = 3.250

3.5.5 Color
Color is the first quality attribute a consumer perceives in food. There was a significant difference in color between weaning foods. The pigment (carotenoids) in corn and soy bean may be responsible for yellow color of the WF4.  
S = 12.82, DF = 3, P = 0.005  
S = 14.57, DF = 3, P = 0.002 (adjusted for ties)

3.5.6 Overall acceptability
Because the adjusted probability value was less than 0.05, there was a significant different at least between two samples. According to the results the highest median value (4.000) and the sums of ranks (93.5) were obtained for the weaning food2. At the same time WF2 got higher ranks for appearance, taste and mouth feel also.  
S = 14.50, DF = 3, P = 0.002  
S = 15.99, DF = 3, P = 0.001 (adjusted for ties)  
Grand median = 3.000

4. Conclusions
This study showed that formulation of weaning food from yoghurt, rice, soybean and mung bean can be achieved successfully while meeting the nutritional requirements of toddlers. According to the chemical, physical and sensory parameters, formulated WF2 was selected as the best one. This low cost weaning food can be introduced as an alternative weaning food for Sri Lankan market especially for the low-income families living in rural areas. The yoghurt and grain flour had a shelf life of 16 and 21 days, respectively. In general, formulate weaning foods supply nutritional requirement of a one to three years old toddler than the commercial available one. Extrusion processing can be a practical technique which can be used to process grains into precooked, dried flours with acceptable physicochemical, nutritional and storage characteristics to produce weaning foods in a large scale but at a low cost. This study revealed that ready to eat complementary food products formulated from locally available food commodities can meet the macro nutritional needs of children. Finally this is a practical local food based approach aimed at mitigating the problem of malnutrition among infants and children in developing countries. Further work can be done on the fortification of the weaning food with vitamin and minerals. Digestibility and bio availability of the macronutrients in these local diets need further investigation. Inclusion of probiotics and determine their survival upon storage.
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Figure 3: Variation in the Titratable acidity of the yoghurt over the experimental time

Table 10: Estimated sums of ranks for the sensory properties of the weaning foods

<table>
<thead>
<tr>
<th>WF</th>
<th>Appearance</th>
<th>Aroma</th>
<th>Taste</th>
<th>Mouth feel</th>
<th>Color</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF1</td>
<td>72.0</td>
<td>76.5</td>
<td>74.0</td>
<td>66.5</td>
<td>61.0</td>
<td>76.5</td>
</tr>
<tr>
<td>WF2</td>
<td>92.0</td>
<td>89.0</td>
<td>93.0</td>
<td>90.0</td>
<td>71.5</td>
<td>93.5</td>
</tr>
<tr>
<td>WF3</td>
<td>81.5</td>
<td>75.0</td>
<td>85.0</td>
<td>85.0</td>
<td>77.5</td>
<td>74.5</td>
</tr>
<tr>
<td>WF4</td>
<td>54.5</td>
<td>59.5</td>
<td>48.0</td>
<td>58.5</td>
<td>90.0</td>
<td>55.5</td>
</tr>
</tbody>
</table>

References


22.09.2011).

