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# Formulation and physico-chemical properties of dietary fiber enhanced low glycemic multi-grain noodles for adults using locally available cereals and legumes

**H.M.T. Herath[1*], K.M. Bhagya Shanaki[2], Dineshka Priyangani[1] and M.S.W. De Silva[2]**
[1]Food Technology Section, Industrial Technology Institute (ITI), No. 503A, Halbarawa Gardens, Thalahena, Malabe, Sri Lanka
[2]Department of Food Science and Technology, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka
theja@iti.lk

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## Abstract

*Non Communicable Diseases (NCDs) are the most prominent health issues in worldwide. A high intake of carbohydrate and fat eventually results in developing NCDs and generous intake of dietary fiber (DF) has a protective effect against NCDs. Whole grain cereals and legumes are rich sources of DF. The objective of present study is to develop high fibre multi-grain noodles with low Glycaemic Index (GI) as an alternative to less healthy noodles available in the market. Whole grain cereals; Brown Rice (BR), Wheat Flour (WF) and whole grain legumes; Chick Pea (CP), Green Gram (GG), Black Gram (BG) were used for formulations. Ash, fat, protein and DF contents of raw materials were found to vary in ranges of 1.34-3.96%, 0.85-6.85%, 10.43-28.17%, and 2.99-12.86% respectively. The possibility of preparation of noodles from different composite flour mixtures were tested evaluating rheological properties and the standard for Total Solid (TS) in gruel values. Results indicated that maximum incorporation of legumes flour is 30%. Three products ($F_4$, $F_5$, $F_6$) which had % proportions of BR: WF, 40:30, 30:40 and 20:50 with 30% legumes flour of CP: GG: BG at ratio of 1:1:1 were selected by considering low levels of TS in gruel values where as $F_6$ having the lowest. DF and Resistant Starch (RS) contents of selected three products ranged from 7.87-9.31% and 0.78-1.13% on dry weight basis respectively. $F_6$ (WF: 50%, BR: 20%, legumes: 30%) had the most sensory preferable product with high DF and low predicted GI.*

**Keywords:** DF, predicted glycaemic index, legumes, noodles, resistant starch.

## Introduction

Non Communicable Diseases (NCDs) including diabetes, cardio vascular diseases, hypertension, obesity, stroke, cancers and gastrointestinal diseases are the most prominent health issues in worldwide including Sri Lanka[1-3]. It is well documented that the global NCD epidemic is associated with recent lifestyle changes of people, especially with inaccurate dietary habits. A generous intake of dietary fiber has a protective effect against NCDs and reduces risk of developing NCDs[4]. The benefits of DF in the diet will be the reduction of post-prandial blood glucose, insulin, serum cholesterol and increase the stomach content consistency and fecal bulk effect etc[5]. The Recommended Daily Allowances (RDA) of DF are 28 g/day for women and 36 g/day for men[6]. The daily mean DF intake of Sri Lankan adults is reported as 18.1 g/day and adults aged over 60 years had the lowest intake of DF[2].

Presently, an interest has been shown to increase the uptake of fibers in the diet. DF enrichment is a current interest area which has to be addressed through nutritional awareness of consumers, government guidelines and changing demographics. Dietary fiber; comprising of soluble fiber and insoluble fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. DF includes polysaccharides, oligosaccharides, lignin and associated plants substances[7]. DFs are naturally found in the plant sources including vegetables, fruits, legumes and whole grains[8,9]. Whole grain cereals and legumes are rich sources of DF due to the presence of fibre rich seed coat. Cereals are the staple food grains for majority of population around the world which contained mainly carbohydrates while legumes are the rich sources of proteins, minerals and other nutrients. In addition, processing into traditional products from those grains, development of value added newer products offers wide array of variety, convenience, quality, cost efficiency and enhanced nutritional values to the consumers.

In the developed countries many convenient foods are prepared by extrusion process using extruder, as it offers a large number of desired characteristics which could be incorporated into the product. Noodles are the one of convenience foods prepared through this system. Normally, noodles are product made from dough prepared from wheat flour and water with or without other optional ingredients followed by kneading, cold extruding through an extrusion press fitted with a die of the desired size or passed through sheeting rolls and cut into the desired length. Product either dried or pre-cooked in steam and dried[10].

Many noodles products are available in the market with high content of digestible starch and very low content of DF. Refined grain products get digested quickly and lead to large spikes in blood sugar[5]. The large spikes are followed by rapid drops which tend to stimulate hunger and call for another high carbohydrate diet[5]. Therefore high intake of carbohydrate leads to increase the risk of NCDs.

Nowadays many people consume instant noodles available in the market. During the processing, instant noodles is precooked in boiling vegetable oil. Since these instant noodles are made to bear a longer shelf life, they are highly processed. They are low in nutritive content with high fat, calories and sodium and are laced with artificial colors, preservatives, additives and flavorings. Most instant noodles are made of *maida*-milled, refined and bleached version of wheat flour and those instant noodles are bad for health as it is highly processed with added flavor and low in nutrition.

Incorporating of whole grain cereals and legumes flour for the preparation of high fiber noodles will not only increase the fiber content of the product, also it leads to increase the nutritional value giving good health benefits. The aim of present study is to develop multi-grain noodles which are high in DF and low in predicted GI. So, locally available legume flours such as CP, GG and BG will be incorporated into whole grain cereal flours of BR and WF to develop DF enhanced, nutritious noodles targeting the adult population especially for the people suffering from NCDs.

## Materials and methods

**Materials:** Paddy (AT-362 rice variety) was obtained from the Rice Research Institute, Ambalanthota.

GG seeds were purchased from local market at Colombo. Those samples were visually inspected for fungal infestation, foreign materials and damaged seeds and samples were cleaned prior to use. Bulk samples of selected paddy and GG seeds were taken for the preparation of flour.

Since good quality CP flour, BG flour and WF are available in local market in the form of sealed pack, they were purchased from the local super markets.

**Preparation of brown rice (AT 362) flour:** Paddy was de-husked using roller mill (Model; Satake -THU35B, Japan) and destoned followed by several rising under running water. Sample was drained for 1h, dried at 60ºC for 5h. Dried rice was ground into grits using cross beater mill in the presence of 3 mm sieve and then ground into flour using cross beater mill in the presence of 0.5 mm sieve. The milled flour samples were sealed in polyethylene bags.

**Preparation of GG flour:** GG seeds were purchased from the local market in Sri Lanka. Seeds were destoned, rinsed several times under running water, drained for 1h, dried at 60ºC for 5 h. Dried seeds were ground into grits using cross beater mill in the presence of 3 mm sieve and then ground into flour using cross beater mill in the presence of 0.5 mm sieve. The milled flour samples were sealed in polyethylene bags.

**Chemicals:** All the chemicals used for the analysis were of analytical grade except ethanol used for dietary fiber analysis-(commercial grade) purchased from Sigma-Aldrich Chemie GmbH, Steinheim, Germany.

**Methods:** Proximate composition analysis was done for the flour samples of raw materials (BR, WF, GG, CP, BG).

**Proximate analysis:** Proximate composition of flour samples of BR, WF, CP, GG and BG were carried out according to the methods described in AOAC, 2012[11]. Parameters were determined in triplicates. Moisture contents of flours were determined according to the oven drying method as described in AOAC, 2012 925.09B[11], applying gravimetric principal. Crude protein content of flours was determined by kjeldahl method as specified in AOAC, 2012 920.87[11] using Kjeldahl heating digestion unit (VELP Scientifica DK 20) and Kjeldahl semi-automatic distillation unit (VELP Scientifica DK 139). Crude fat content was determined by soxhlet extraction method according to AOAC, 2012 920.39C[11] using Automatic extraction systems Soxtherm (C. GERHARDT GMBH & CO. KG Analytical Systems). Crude fibre content was determined according to the method described in AOAC, 2012 962.09E[11] using Fibertec™ M6 Fibre Analysis System (FOSS-1020 HOT EXTRACTOR). Ash content was determined as specified in AOAC 2012 923.03[11] by dry ashing method with gravimetric principal. Total carbohydrate content was determined according to the method described by Sompong et al[12].

**Determination of total DF content:** Total DF contents of flour samples were determined by the enzymatic gravimetric method as described by Asp et al 1983[13]. In this method, starch and protein are digested with enzymes into small fragments. Ethanol is added to the filtrate to precipitate the soluble fiber and both soluble and insoluble fiber is recovered by filtration.

**Formulation of noodles:** Composite flour mixtures for the preparation of noodles were prepared by mixing whole grain flours of BR (AT 362), WF, GG, BG and CP in different ratios as formulation procedures described in the Table-1.

The legume flour mixture (CP, GG, BG) was incorporated at 40% and 30% levels to the BR and WF to obtain the maximum level of addition of legumes flours. At the beginning of trials wheat flour and rice flour were mixed in different ratios with intension of obtaining more rice flour incorporation to noodles preparation. However in this study, WF (whole grain) incorporation had to be gradually increased compared to rice flour in the formulae in considering the retaining of rheological properties of noodles. The possibility for the preparation of noodles was tested by using different flour combinations as shown in Table-1.

**Table-1:** Different flour combinations used in noodles formulation.

| Trial No. | Product Name | Percentage ratios in composite flour mixture (BR : WF: CP : BG : GG) |
|---|---|---|
| 1 | F1 | 60 : 00 : 13.33 : 13.33 : 13.33 |
| 2 | F2 | 30 : 30 : 13.33 : 13.33 : 13.33 |
| 3 | F3 | 50 : 20 : 10 : 10 : 10 |
| 4 | F4 | 40 : 30 : 10 : 10 : 10 |
| 5 | F5 | 30 : 40 : 10 : 10 : 10 |
| 6 | F6 | 20 : 50 : 10 : 10 : 10 |

(BR-Brown Rice, WF-Wheat Flour, CP-Chick Pea, BG-Black Gram, GG-Green Gram).

Whole grain flours were weighed according to the selected combination as given in Table-1 to obtain the final total weight of flour mixture was 1kg. Dry mixing of the flour mixture was done for 15 min in the mixer (Model; Hobart CE.100, England). Then sufficient amount of water was added while mixing in mixer for further 20 min. The requirement of adding amount of water was different according to the composition of the flour mixture. So the water was added until the texture of flour mixture became to the point at which an unbroken small flour ball could be able to make by hand.

Steaming of composite flour mixture was done for only trial 1 where for the purpose of gelatinization of rice flour and in trial 2, steaming was performed only to rice flour portion. In other trials, steaming of the flour mixture was not performed after mixing of the flour mixture due to the disruption of gluten structure of the WF during the steaming. So in trials 3, 4, 5 and 6 with the increment of incorporation of WF, steaming of the flour mixture was not performed. After mixing of the flour mixture, extrusion was done in single screw cold extruder. Steaming of noodles was done for 15 min for the purpose of gelatinization. After drying at 45°C for 3 h in a tray dryer, they were allowed to cool and then packed in polyethylene bags.

**Determination of physical properties of noodles:** Determination of physical properties was carried out for the selected three formulated noodles products ($F_4$, $F_5$, $F_6$) in triplicates as given in Table-3. Except those, physical properties of two types of commercial noodles products (100% wheat noodles and 100% red rice noodles: Brand name of "Harishchandra") were determined for the purpose of comparison with market samples and the developed noodles products.

**Determination of TS in gruel of noodles:** Total Soluble Solids in gruels of all formulated noodles were determined according to the method specified in Sri Lankan standard 420 1989[10] for pasta products.

25.0 g of samples of developed noodles and commercial noodles were cooked for 5 min in 250 ml of water in lipless beaker with occasional stirring. Cooked noodles were allowed to drain through a strainer for 5 min and the volume of gruel was measured. A 20 ml of the gruel was pipetted out in triplicates into previously dried weighed suitable dishes, after stirring the content well to give an even distribution of the solid content. They were evaporated to dryness on a water bath (Model; MEMMERT). The dishes were transferred to a hot drying-oven maintained at 105 ± 2°C and heated for 2 h. After dishes were cooled in desiccators, weighed the content. The process of heating for 30 min, cooling and weighing was repeated till obtain the constant weight. The percent loss of TS in noodles was determined by obtaining the TS loss to initial weight.

**Determination of cooking time of noodles:** Cooking time of selected developed noodles and the commercial noodles products were determined according to the method specified in Sri Lanka standard 420 1989 for pasta products[10]. A 25g of product was placed in 250mL of boiling water.

A portion of the product was taken at the end of every minute and checked whether the product was sufficiently cooked. (Note-Sufficiently cooked product has an elastic texture without hard or gritty center when biting) On complete cooking, white hard core is not remained when squeezed between the transparent plates. The time taken for complete disappearance of white core was considered as cooking time.

**Sensory evaluation:** Three selected developed noodles samples of ($F_4$, $F_5$, $F_6$) were presented for the sensory evaluation. Selected products were cooked in boiling water for five min. Then the noodles were allowed to drain through a strainer for 5 min and it was tempered with equivalent amount of oil, onion and salt. Samples were served to sensory panel including twelve trained sensory panelists for sensory evaluation. They were instructed to evaluate the three samples with regards to given sensory characteristics such as color, taste, flavor, texture and overall acceptability and to indicate the intensity of the specified characteristics by giving the appropriate number related to the 9 point hedonic scale.

**Hedonic scale:** Like extremely-9, Like very much-8, Like moderately-7, Like slightly-6, Neither like nor dislike-5, Dislike slightly-4, Dislike moderately-3, Dislike very much-2, Dislike extremely-1.

**Chemical analysis of the selected developed noodles and commercial noodles products:** Selected 3 formulated noodles products ($F_4$, $F_5$, $F_6$) and 2 commercial noodles products were ground into fine powder to pass through 0.5 mm sieve using the centrifugal mill. Powdered noodles samples were packed and sealed in polyethylene bags for analysis.

**Determination of *in-vitro* starch digestibility of noodles:** *In-vitro* starch digestibility of selected formulated noodles and market noodles products were determined using the modification of the method described by Thompson et al[14].

The noodles samples were crushed in to coarse powder using motor and pestle. (The particle size should be approximately equal to the size which can be broken down by teeth).

Available carbohydrate content of noodles ($F_4$, $F_5$, $F_6$) were calculated using the 'by difference' method.

Available carbohydrate content=100 - (% crude protein + %crude fat + % moisture + % ash + % total dietary fiber).

***In-vitro* starch digestion:** Portions of available carbohydrate (1.000 g) of the sample, human saliva (5ml) and distilled water (10 ml) were placed in to a dialysis bag (13 cm length, 4.5 cm width, 4.8 nm pore diameter with molecular weight cut off: 10,000-12,000 Daltons). Dialysis bags were previously warmed in 40% ethanol solution at $60^oC$ for 10 min and they were stored in 0.001 M $NaHCO_3$ solution at $4^oC$ prior to dialysis. Contents of dialysis tubing were gently massaged to mix. Then dialysis tubing was suspended in 800 mL of distilled water at $37^{\circ}C$ with continuous agitation. 1 mL of dialysate was pipetted into screw cap tubes in triplicates at time intervals 1, 2, and 3 h after hydrolysis. Same procedure was followed for white bread which was used as the reference food.

**Reducing Sugar Assay:** Reducing sugar was assayed in solutions as methods described by Miller[15] and Saqib et al. [16].

1 mL of sugar solution from series of standard D-Glucose solutions of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 mg/mL concentrations was added to 4 mL of DNS reagent and mixed well. Tubes were placed in boiling water bath for 5 min, transferred to ice to cool down rapidly and brought to room temperature by placing them in water bath. Absorbance was measured at 540 nm, using spectrophotometer (UV-1601, Japan). Standard curve for standard D-glucose was plotted concentration *vs*. absorption.

1 mL of dialysate from *in-vitro* digested samples of developed $F_1$, $F_2$, $F_3$ and commercial noodles were pipetted out in to a screw cap tube containing 4 mL of dinitrosalicylic (DNS) reagent and the same procedure at 1h, 2h and 3h was followed as previously described for standard D-glucose. The reducing sugar content with respect to each absorbance value was obtained from a standard curve which was previously prepared for D-glucose. Hydrolysis curve was plotted % starch hydrolysis *vs* time for three products.

**Estimation of GI:** GI calculations were done according to Goni et al.[17] and Germinie et al.[18]. The area under the hydrolysis curves of the test food and the reference food were calculated and Hydrolysis Index for products was calculated.

$$\text{Hydrolysis Index (HI)} = \frac{\text{Area under the curve of test food}}{\text{Area under the curve of reference food}} \times 100$$

$$\text{Predicted GI value } (GI_{HI}) = 39.71 + (0.549 \times HI)$$

Since above equation is developed for values reported based on the GI of glucose=100, it should be converted to a value based on bread by multiplying by 0.7.

$$\text{Adjusted predicted GI value} = GI_{HI} \times 0.7$$

**Determination of RS content:** The RS content of the selected formulated noodles and market noodles products were determined using an enzymatic assay (using megazyme assay kit). This method allows the measurement of RS, solubilised starch and total starch content of samples.

The procedure has been subjected to inter laboratory evaluation under the auspices of AOAC International and AACC international and accepted by both associations; AOAC Official Method 2002.02; AACC Method 32-40.01[19].

**Statistical analysis:** Data were analyzed using Microsoft Office Excel (Microsoft Corporation®) and IBM SPSS 16 (SPSS Institute, Chicago, USA), SAS and MiniTab 15 software. Three replicates were taken in each analysis and Mean and Standard Deviations were calculated. Difference between the formulations was evaluated by one way analysis of variance (ANOVA) at 5% significant level. Kruskal Walli"s test (non parametric analysis) and mean separation technique were used to analyze sensory evaluation results SPSS 16.

## Results and discussion

In the present study, the whole grain cereals and legumes were used in the formulation of noodles instead of using wheat flour solely. Whole grains are reported to be rich in DF and the components with high functional properties[8]. Legume flour incorporation in the formulation of noodles was increased protein content and DF content while improving the protein quality of product.

In the formulation process BR and whole grain WF were used as the cereal flour while whole grain CP, BG and GG were used as legumes flours. Even though wheat is not a locally cultivated crop in Sri Lanka, incorporation of WF is very essential to retain the acceptable rheological properties in multi-grain noodles.

In this context whole grain wheat flour was used instead of refined wheat flour for the purpose of increasing fibre content.

**Composition analysis of raw materials:** Despite great variation in the macronutrient composition of cereals and legumes, their basic seed structure is the same. Mature seeds contain three major components, the seed coat (testa), the embryo and the endosperm. The composition of ingredients used presented in Table-2.

**Table-2:** Nutrient composition of raw materials.

| Ingredient | Ash content (%)* | Fat content (%)* | Protein content (%)* | Dietary fiber content (%)* | Available Carbohydrate content (%)** |
|---|---|---|---|---|---|
| Brown Rice | 1.34±0.01$^{e}$ | 2.45±0.05$^{b}$ | 10.43±0.04$^{e}$ | 2.99±0.01$^{e}$ | 82.79 |
| Wheat Flour | 1.53±0.01$^{d}$ | 2.25±0.10$^{c}$ | 13.35±0.14$^{d}$ | 12.68±0.04$^{b}$ | 70.19 |
| Chick Pea | 3.09±0.01$^{c}$ | 6.85±0.04$^{a}$ | 22.54±0.05$^{c}$ | 11.27±0.04$^{c}$ | 56.25 |
| Green Gram | 3.48±0.01$^{b}$ | 0.89±0.01$^{d}$ | 26.55±0.05$^{b}$ | 10.58±0.03$^{d}$ | 58.50 |
| Black Gram | 3.96±0.02$^{a}$ | 0.85±0.01$^{d}$ | 28.17±0.20$^{a}$ | 12.86±0.04$^{a}$ | 54.16 |

Values are presented as Mean ± SD of three independent determinations, *Values are given in dry basis **Carbohydrate content calculated by difference, Different superscripts in a column represent significantly different samples.

In the present study, among the raw materials, significantly the highest ($p \leq 0.05$) fat content was found in CP (6.85%) and it was lower in BG (0.85%) and GG (0.89%). Normally, GG and BG seeds are known as low-fat seeds among *Leguminosae* family. The presence of low fat content in grains is an advantage during processing into flour, since unlike oil seed legumes such as soyabean, it is not required for defatting step prior to flour production. According to the results it is seen that, protein content of legumes was significantly ($p \leq 0.05$) higher than the protein content of the cereals. As expected the protein content of pulses was found to be 2-3 folds greater than that of the cereals. Among the raw materials BG contains significantly ($p \leq 0.05$) high amount of protein (28.17%). These findings regarding the protein content are conformity with the values described by Kadam et al.[20]. Current results are resemblance with findings of another researches, which was reported that protein content of GG (*P. aureus* and *Vigna radiate)* were 27.5%[21] and 24.08%[22] respectively.

The most important constituent in present study was total dietary fiber content. It was found that DF content was significantly high in BG (12.86%) among the raw materials and it was lowest in BR (2.99%). Whole grain cereals and legumes had higher content of DF than other food groups. Fibers are present in two forms of soluble and insoluble[23]. In most legumes consumed by humans, the DF content ranges from 8% to nearly 28%, with soluble fiber in the range 3.3% to 13.8%. Soluble fiber reported to be slow down the absorption of lipids and lower blood cholesterol[23]. Available carbohydrate contents were found to be comparatively higher in cereals than the legumes.

**Formulation of noodles:** Exploring the possibility of incorporating novel ingredients in commonly consumed foods with the means of improving the nutritional profile and functional properties has become a novel trend in food industry. The composite flour mixtures of cereal and legume provide the complementation of nutrition balance of diet. Legume proteins are low in methionine and cysteine like sulfur containing amino acids where as cereal proteins are deficient in lysine. So the combination of both grains improves the protein quality of product. For the formulation of DF enhanced multi-grain noodles, different composite flour mixtures were prepared by mixing the flour of whole grain cereals and legumes in different ratios as given in Table-3.

**Table-3:** Total solids in gruel of developed noodles.

| Product | Total solids in gruel (%)* | Possibility of forming noodles |
|---|---|---|
| F1 | 11.22±0.24$^{a}$ | Not possible |
| F2 | 9.40±0.73$^{b}$ | Not possible |
| F3 | 6.77±0.06$^{c}$ | Not possible |
| F4 | 6.52±0.03$^{c}$ | Possible |
| F5 | 6.51±0.11$^{c}$ | Possible |
| F6 | 5.62±0.13$^{d}$ | Possible |

Values are expressed as Mean ± SD of three independent determinations, Different superscripts in a column represent significantly different samples.

According to the reported previous studies in formulation of high protein pulse based noodles, legumes flour had been incorporated at level of 10% to 40% with refined wheat flour[24]. The study done by Vani and Manimegalai[24] reported that the maximum possible incorporation of legumes flour was 40% with refined wheat flour, without affecting to the overall quality of noodle. However in the present study legume flours were incorporated with whole grain cereal flours (wheat and brown rice) instead of refined wheat flour due to the high fiber concept. In the previous studies, it has been shown that the addition of high fiber sources to the formulation of noodles decreases the extensibility of dough showing resistance to extension. Most probably, maximum possible incorporation of legume flours to the whole grain cereal flours would be less than 40% in the noodles formulation by previous literature[24]. In the present study incorporation of 40% legume flour was not possible due to the products with 40% of legumes flour had very poor textural properties. The TS in gruel of those products were found to be very high (11.22% in $F_1$ and 9.40% in $F_2$ respectively) showing the high amount of solid loss during cooking noodles. Further the breakable nature of those products was high after the cooking and even during the extruding.

Therefore 40% incorporation of legumes flour was not possible in preparation of noodles due to the poor binding properties of legumes flour.

When 30% of whole grain legume flours were incorporated with whole grain cereal flours the textural properties of noodles was become acceptable. The TS in gruel of noodles was nearly 6% in those products which are having 30% legumes flour. The DF content of three legumes: CP, GG and BG were 11.27%, 10.58% and 12.86% respectively. Since there were not much variation observed in DF content of three legumes, legumes flour was incorporated in 1: 1: 1 ratio within the formulae. Even though DF content of BG (12.86%) was slightly higher, it is not possible to incorporate in high amounts since it may affects to the taste due to presence of flavonoid compound. So, CP: BG: GG were kept as 10%: 10%: 10% (30%) in the formulae. Remaining 70% was whole grain cereal flours (BR and WF). Since DF content of whole grain WF (12.68%) was significantly higher than the DF content of BR (2.99%), the amount of WF incorporation was gradually increased in the formulae during the trials. When percentage WF was increased in the formulae, the TS in gruel of noodles decreased and textural properties became more acceptable. It is due to the gluten structure of the wheat[24]. The lowest TS in gruel was shown by the product $F_6$ which is having maximum WF incorporation.

The TS in gruel is a very important factor in noodles processing[25]. Although the product is rich in nutrients, if TS in gruel is high the solid loss to the water is high during the cooking of noodles. Hence many of the nutrients can be leached out during the cooking of noodles. According to the Sri Lanka Standards, TS in gruel should be less than 6% for rice noodles[26] and it should be less than 10% for wheat noodles[10].

Since unavailability of standard for the TS in gruel for developed product multi-grain noodles, the best product will be the noodles with solid loss during cooking is very low value. Therefore three possible products having acceptable textural properties, relatively lower levels of TS in gruel with better texture, were selected among the formulated products ($F_4$, $F_5$ and $F_6$) (Table-3).

**Sensory evaluation:** According to the results as shown in Table-4 in the sensory evaluation of color, texture, taste, flavor and overall acceptability of three products ($F_4$, $F_5$, $F_6$) were significantly different ($P \leq 0.05$) at 5% significant level. Product $F_6$ was the most preferable product with respect to tested all the sensory attributes (color, texture, taste, flavor, overall acceptability). In those three formulae, legumes flour composition was same while cereal flour composition was varied. Different proportions (%) of BR and whole grain WF in $F_4$, $F_5$, $F_6$ were 40:30, 30:40 and 20:50 respectively and proportions of CP, BG, GG were 10:10:10 in all three products. Product $F_6$ contained the highest content of WF and the lowest content of rice flour among the three products. The proportion of WF is increased and BR flour percentage is decreased in the formulae due to the retaining of textural properties while taste became more acceptable. Textural property is mainly depending on the presence of gluten structure of wheat. The color of noodles was progressively darker as the noodles contained considerable levels of brown rice flour.

**Table-4:** Probability values and mean ranks obtained by $F_4$, $F_5$ and $F_6$ products for sensory attributes.

| Sensory attribute | Mean rank of $F_4$ | Mean rank of $F_5$ | Mean rank of $F_6$ | P- value |
|---|---|---|---|---|
| Color | 13.25 | 19.75 | 22.50 | 0.049 |
| Texture | 13.58 | 18.42 | 23.50 | 0.029 |
| Taste | 10.54 | 19.79 | 25.17 | 0.002 |
| Flavor | 11.38 | 19.54 | 24.58 | 0.005 |
| Overall acceptability | 10.67 | 18.83 | 26.00 | 0.001 |

**Proximate composition of noodles:** In the nutritional point of view, ash, fat, protein and DF contents in developed noodles were significantly high ($p \leq 0.05$) with use of composite multi-grain flour than the commercial wheat and rice noodles (Table-5).

**Table-5:** Nutrient composition of developed noodles and commercial noodles.

| Formulation | Ash content (%)* | Fat content (%)* | Protein content (%)* | Dietary fiber Content (%)* | Available Carbohydrate Content (%)** | Resistant Starch content (%)* |
|---|---|---|---|---|---|---|
| $F_4$ | $2.11 \pm 0.03^a$ | $0.55 \pm 0.03^b$ | $19.37 \pm 0.08^c$ | $7.87 \pm 0.00^c$ | 70.10 | $0.82 \pm 0.05^b$ |
| $F_5$ | $2.13 \pm 0.02^a$ | $0.69 \pm 0.03^a$ | $20.00 \pm 0.09^b$ | $8.68 \pm 0.02^b$ | 68.50 | $1.13 \pm 0.01^a$ |
| $F_6$ | $2.13 \pm 0.02^a$ | $0.58 \pm 0.03^b$ | $20.69 \pm 0.10^a$ | $9.71 \pm 0.02^a$ | 66.89 | $0.78 \pm 0.00^{b,c}$ |
| Commercial wheat noodles | $0.70 \pm 0.01^c$ | $0.28 \pm 0.02^c$ | $16.75 \pm 0.14^d$ | $4.34 \pm 0.01^d$ | 77.93 | $0.76 \pm 0.01^c$ |
| Commercial rice noodles | $1.23 \pm 0.00^b$ | $0.12 \pm 0.02^d$ | $10.84 \pm 0.28^e$ | $3.33 \pm 0.11^e$ | 84.48 | $0.67 \pm 0.03^d$ |

Values are expressed as Mean ± SD of three independent determinations, *Values are given in dry weight basis, **Calculated by difference, Different superscripts in a column represent significantly different samples.

Since legumes are rich sources of protein, protein contents of the multi-grain noodles were significantly higher than the commercial wheat and rice noodles. It was highest in product $F_6$ which is having the highest incorporation of whole grain WF. Since protein content is higher in WF than BR, the product with the highest WF had the highest protein content. On the other hand, since whole grain cereals and legumes are rich sources of DF, total DF contents of the multi-grain noodles were found to be nearly 2 fold higher than the commercial wheat and rice noodles. DF was highest in product $F_6$ (9.71 %) which is having highest incorporation of WF. Since DF content is higher in WF than BR the product with highest WF had the highest DF content. Lowest DF content was found in commercial rice noodles. Moisture content of developed noodles was lower than 12%. The available carbohydrate content indicates the metabolizable carbohydrate content and it was highest in commercial rice noodles and lowest in product $F_6$ (50% WF, 20% BR with 30% legumes) and lowest in commercial rice noodles. Product $F_6$ contains lowest level of available carbohydrate and it was highest in commercial rice noodles. Moisture contents of products were ranged in between 9.58 - 11.64% and it was lowest in commercial wheat noodles and highest in product $F_5$.

**Resistant starch content of noodles:** Resistant starch content is slightly higher in multi-grain noodles than commercial wheat or the rice noodles (Table-5) due to the incorporation of RS type-1 rich whole grain cereals and legumes[27]. In noodles products RS type- 3 i.e. retrograded starch formed by recrystallization of starch chains during storage after cooking is available[28].

***In-vitro* starch digestibility of noodles:** According to the *in-vitro* starch digestibility studies (Table-6), commercial wheat noodles is an intermediate GI food since predicted GI is in between 56-69. Commercial rice noodles and other three developed multi-grain noodles products can be categorized as low GI (GI<55) foods. Low GI foods increases post prandial blood glucose level at a comparatively slower rate over others. Food containing high DF, fat and protein contents and low available carbohydrate contents may collectively generate this result[17]. Starches decompose into glucose by digestive enzymes (more precisely alpha-amylase and additionally pancreatic amylase) and enter in to blood stream increasing blood glucose levels. Starch granules are made up of two types of molecular components; amylose and amylopectin. Starches with high amylose content are less susceptible to gelatinization (break down into glucose) and make to low GI. Starch in pulses contains higher amount of amylose (33-66%) than in cereal starches (15-28%) which causing to low GI. The fiber in foods interferes with amylase action and contributes to reduce glucose absorption. Basically, the fibers that directly or indirectly contribute to reducing intestinal glucose absorption[17].

**Physical properties of noodles:** TS in gruel is higher in developed noodles than the commercial wheat and rice noodles (Table-7). It is due to the incorporation of non wheat flour component, specially due to the legumes flour. The binding properties of legumes flour are weak when compared with the wheat flour. Among the three developed products, the lowest TS in gruel was found in product $F_6$ which is having maximum WF incorporation (50%). TS in gruel of $F_6$ was obtained as 5.62% while it was 5.28% in commercial wheat noodles. According to the SLS standards, TS in gruel should be less than 6% for rice noodles[26] while it should be less than 10% for wheat noodles[10]. Therefore among the developed products, $F_6$ had the lowest TS in gruel showing values lower than the recommended maximum values for the commercial wheat and rice noodles. According to Grybowski and Donnelly[29] the TS loss in noodles during cooking is closely related to protein content while Dexter et al.[30] reported that denaturation of a thin protein film during high temperature drying of pasta might have a role for improved surface stability (surface integrity) resulting in lower cooking loss.

**Table-6:** Glycemic index values of developed noodles and commercial noodles products.

| Product | AUC | HI (%) | Predicted GI | Adjusted predicted GI |
|---|---|---|---|---|
| $F_6$ | 10.47 | 8.34 | 44.29 | 31.00 |
| $F_5$ | 8.63 | 6.88 | 43.49 | 30.44 |
| $F_4$ | 22.80 | 18.18 | 49.69 | 34.78 |
| Commercial rice noodles | 43.35 | 34.56 | 58.68 | 41.08 |
| Commercial wheat noodles | 99.70 | 79.47 | 83.34 | 58.34 |
| Wheat bread | 125.45 | 100 | 94.61 | 66.23 |

(AUC-area under curve, HI-hydrolysis index, GI-glycemic index).

**Table-7:** Physical properties of developed noodles and commercial noodles products.

| Product | Total solids in gruel (%)* | Cooking time (min) |
|---|---|---|
| $F_6$ | $5.62{\pm}0.13^b$ | $5.00^a$ |
| $F_5$ | $6.51{\pm}0.11^a$ | $5.00^a$ |
| $F_4$ | $6.52{\pm}0.03^a$ | $5.00^a$ |
| Commercial rice noodles | $1.59{\pm}0.03^d$ | $4.50^b$ |
| Commercial wheat noodles | $5.28{\pm}0.02^c$ | $5.00^a$ |

*Values are expressed as Mean ± SD of three independent determinations, Different superscripts in a column represent significantly different samples.

The optimum cooking times for dry noodles in boiled water was determined by visual disappearance of white noodle core after 4.5 min in commercial rice noodles and it was 5 min in all other products. High protein content may cause longer cooking time. According to the Vani and Manimegalai[24] the noodles made with blended legumes flour showed an increased in water uptake, weight gain after cooking and increased the cooking time. Therefore in this study, the high fiber and high protein contents in multi-grain noodles results in longer cooking time than the commercial rice noodles. Total solids (TS) in gruel of developed noodles were significant higher than the TS in gruel of commercial noodles. It was lowest in commercial rice noodles (1.59%) and highest in product $F_4$. But among the selected three developed products lowest level of TS in gruel was found in product $F_6$ (5.62%).

Considering all parameters of chemical, physical and sensory properties of noodles, $F_6$ was the best product which had the highest DF content, the highest protein content, the lowest TS in gruel, the best textural properties, the lowest available carbohydrate content, a low GI food and the most sensory preferable product. Therefore combination of 50% WF, 20% BR, 10% CP, 10% BG, 10% GG was selected as the best formula to develop DF enhanced multi-grain noodles without negative impact in rheological properties and sensory properties.

**Nutrient composition of $F_6$ per serving:** In the present study, the serving size of noodles was determined as 250 g (cooked weight) or 85 g (dry weight) by the consumer trails.

**Table-8:** Nutritional composition of $F_6$ per serving.

| Component | Amount per serving |
|---|---|
| Energy | 302.21 kcal |
| Protein | 16.60 g |
| Fat | 0.47 g |
| Ash | 1.71 g |
| Available carbohydrate | 53.66 g |
| Dietary fiber | 7.79 g |

Per serving of product $F_6$ contains 16.6 g of protein and fat content is less than 3g per 100g of the product (Table-8). Hence $F_6$ is a high protein and low fat containing product according to the Sri Lankan regulations Food Act 1989[31] (Low fat <3g per 100g/ High protein > 12g/serving). Presently, there is no any guidelines have been introduced to claim a food product as "high fiber" in Sri Lanka. According to the US statement if a product needs to be claimed as a high fiber product, it should contain 5g of DF per serving or more than 20% from the daily value of DF. Product $F_6$ is having 7.79 g of DF per serving and it is 31.16% from the daily value of DF. So, $F_6$ can be categorized as a high fiber product according to the US guidelines[32].

## Conclusion

According to the results obtained, maximum possible incorporation of legumes flour to whole grain cereals flour in noodles formulation was 30% without affecting to the sensory and textural properties. The product with 50% WF, 20% BR, 10% CP, 10% BG, 10% GG had the highest DF content, highest protein content, lowest TS in gruel, best textural properties, lowest available carbohydrate content, a low GI and it was the most sensory preferable product among the developed products. So it was selected as the best formula ($F_6$) to develop DF enhanced multi-grain noodles without affecting to the rheological and sensory properties.

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