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RESEARCH ARTICLE

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Development of pasta using composite flour of sweet potato (*Ipomoea batatas*), soy (*Glycine max*) & rice (*Oryza sativa*) flours

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Abstract: Pasta made from wheat flour is a convenience food globally. This study investigates the use of composite flour to reduce wheat flour consumption in Sri Lanka and develops a blend of locally available ingredients, *viz.*, sweet potato (*Ipomoea batatas*) accession 'Carrot Bathala', soy (*Glycine max*), and rice (*Oryza sativa*), using a Taguchi orthogonal experimental design. Four samples (T_2, T_3, T_4, and T_8) were selected for final evaluation through preliminary sensory evaluation. The ratios of the three ingredients for samples T_2, T_3, T_4, and T_8 were 50:30:20, 41.6:33.3:25, 60:20:20 and 63.6:27.2:9, respectively. A pasta made from 100% wheat flour served as a control. The sensory evaluation was performed by 30 untrained panellists utilizing a 9-point hedonic scale and the results were analysed using a one-way Friedman test with a confidence interval of 95%. All treatments scored significantly higher in sensory properties than the control, with T_2 achieving the highest scores for appearance, taste, hardness, and overall acceptability. From nutritional perspective, T_2 contained significantly more fat (2.19%), fibre (2.54%), energy (510.3 kcal/100 g), ash (3.35%), and protein (14.57%) compared to the control. However, moisture (10.90%), carbohydrate (74.31%), and acid-insoluble ash (0.05%) were significantly higher in the control. T_2 had the lowest cooking time and water absorption (91.35%) but higher cooking loss (11.25%). The highest values of hardness, chewiness, and gumminess can be observed in pasta made from composite flour. The composite flour pasta met SLS420:2019 standards, suggesting its potential as a gluten-free alternative that could be commercialized in Sri Lanka.

Keywords: Composite flour, pasta, rice, soy, sweet potato.

INTRODUCTION

'Pasta' is an Italian word meaning 'dough' and the production and consumption of pasta have historically been predominant in Italy. Because it is more convenient, palatable, and has a longer shelf life than other bakery products like bread, pasta is consumed widely over the world. Semolina made out of wheat is the main ingredient in making pasta (Nilusha *et al.*, 2019). However, the preparation of pasta using composite flour with or without adding wheat flour has high potential in developing countries like Sri Lanka due to the non-availability of the wheat crops.

Rice is a staple food for the Sri Lankan community, providing a typical Sri Lankan with 45 percent of his daily calorie intake and 40 percent of his total protein needs. In addition, rice is rich in carbohydrates and fibres, has a low calorie, fat and cholesterol content and is also a gluten-free foodstuff (More *et al.*, 2013). The quality of products made from rice is strongly influenced by the content of amylose and amylopectin (Fari *et al.*, 2011).

Rice is the principal cereal grown for direct human consumption as a single grain. It is also consumed in the form of noodles, rice cakes, breakfast cereals, fermented sweet rice and as a snack food prepared by extrusion. The rice is also used to make beer, wine and mulled wine

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(Bor, 1999). Rice flour produced by grinding whole rice grains or broken rice has resulted in a significant increase in the variety of products based on rice such as gluten-free bread, rice cakes, rice noodles, and baby food (Ronie & Hasmadi, 2022).

Soybean (*Glycine max*) belongs to the legume family. Dry soybean contains 40% protein, 20% oil, 35% both soluble (sucrose, raffinose, stachyose, etc.) and insoluble (dietary fibre) carbohydrates, and 5% ash. The moisture content of fresh soybeans is roughly 14%. Soy protein products are easily digestible by humans. Human digestion of soy protein ranges from 92% to 100%. The structure and amino acid composition of protein in soybean significantly impact the performance of soybean in product development, such as proper binding of water and fat emulsification and foaming (Jooyandeh, 2011). Traditionally, soybean was used mainly as fermented (*e.g.*, sauce, miso, natto) and non-fermented (*e.g.*, oil, milk, tofu, flour) food products. With the discovery of its structural and functional characteristics, soybeans are now used as a raw material in the form of whole beans or partially or fully defatted cakes or meal for the production of various soy-based food products. Soybean flour can also be made from partially or fully de-fatted beans (cake or meal) and used in the production of bakery products, soybean protein isolates and concentrates, extruded and processed foods, etc. (Nawab, 2010).

The sweet potato (*Ipomoea batatas*) is a tuberous-rooted perennial plant belonging to the Convolvulaceae family (Senanayake *et al*., 2013). Sweet potatoes are the fifth and seventh most significant food crops produced in the world and in developing nations, respectively (Parle & Monika, 2015). Compared with other root tuber crops, the sweet potato has the following positive attributes: wide production geography, adaptability to marginal conditions, short production cycle, high nutritional value, and sensory versatility in terms of flesh colours, taste, and texture. Besides, sweet potatoes are declared as first rank (superfood) in nutrition among vegetables due to their high nutritional value and numerous health benefits including anti-cancer, anti-diabetic, etc. (Islam, 2024). Furthermore, sweet potatoes contain magnesium, a crucial mineral, which promotes relaxation, calmness, and nerve health (Parle & Monika, 2015). Sweet potatoes contains β-anthocyanins, phenolics, dietary fibre, ascorbic acid, folic acid, and minerals (Bovell-Benjamin, 2007). Orange flesh sweet potato is especially high in β-carotene (*i.e.*, precursor to vitamin A) which will help to promote the consumption of sweet potatoes among children and pregnant women in Sri Lanka. Furthermore, it contains several antioxidants which may reduce the risks of cancers, and is useful for balancing blood pressure and improving the digestion of consumers (Chintha, 2020). Sweet potatoes are broadly grown as a staple food in many developing countries. In Sri Lanka, sweet potato is a traditional crop grown mainly in the wet and intermediate zones and about 35,000 tonnes are produced annually (Department of Census and Statistics, 2019). Sweet potatoes are traditionally consumed after boiling or cooking and it is processed in various ways for different uses including cleaning and sorting, cutting or slicing, cooking or boiling, mashing or pureeing, drying, freezing, canning or preserving, roasting or frying, baking, fermentation, and industrial processing (Islam, 2024). The sweet potato flour can be produced after the tubers have been cleaned, peeled, cut, dried and ground into a fine powder which can be stored for a longer period and used in various food products including bakery products, cakes, biscuits, breakfast foods, noodles, pasta, sauces, and fermented drinks (Dereje *et al.,* 2020). Sweet potato starch is used in traditional noodles, vermicelli, as a thickener or as a sugar syrup, which is used in many processed food products. Sweet potato starch and sugar are also used to produce fuel alcohol, monosodium glutamate, microbial enzymes, citric acid, lactic acid and other chemicals (Truong *et al*., 2018).

Sweet potato has been produced and consumed by Sri Lankan for ages now, and has a wide export potential (EDB, 2021). Today, most people are in the habit of consuming fast food products because of their busy lifestyles. Hence, sweet potato consumption is declining gradually compared with past years. Therefore, there is a better opportunity to develop a convenient food by using sweet potatoes, to promote the sweet potato among people, especially children. Pasta products have not been developed so far in Sri Lanka using these ingredients, according to the available literature.

In Sri Lanka, wheat flour is one of the most consumable ingredients for making different food especially, bread, roti, noodles, etc. However, due to its high price, consumers are unable to purchase them. Therefore, subsidiary foods must be developed as replacements for products made out of wheat flour. Pasta from composite flour can be taken as a subsidiary for the main meal. The objective of this study was to develop pasta with a composite flour mixture of high nutritional value made from locally available flour types like rice, soy and sweet potato.

MATERIALS AND METHODS

Material collection

Mature tubers of orange flesh sweet potato commonly known as 'Carrot Bathala' were collected from the Kubaloluwa farm in Gampola, Sri Lanka. The other ingredients, soybean and raw white rice were collected from the supermarket. Preparation of raw materials and identification of their physicochemical properties (physical properties and proximate analysis) were done in the Biosystems Technology laboratory, Faculty of Technology, South Eastern University of Sri Lanka. The pasta preparation and sensory evaluation studies were done in the Biosystems Technology Laboratory, Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka.

Preparation of sweet potato

The sweet potato tubers were rinsed with potable water, peeled by hand, and trimmed using a knife to remove any undesirable portions. Then, the tubers were cut into small pieces using a knife (Senanayake *et al*., 2014). Thereafter the pieces were blanched for 5 min using a steamer (Julianti *et al*., 2019). After that, the sweet potato pieces were dried in a forced air drier (Model No: BOV-V230F, China) at 65 °C until the moisture content was reduced up to 12%.

Preparation of soy

Soy flour preparation was done according to the method of Bolarinwa & Oyesiji (2021). First, the soybeans were cleaned properly to remove impurities such as stones and then washed with portable water. Thereafter, the soybeans were dried under sunlight until a moisture content up to 12% was reached. Then, the soybeans were dehulled.

Preparation of rice

First, raw white rice was cleaned thoroughly to remove unwanted particles such as stones and sticks. Then the rice was washed with portable water. Then, the rice was dried under sunlight until a moisture content up to 12% was reached.

Preparation of flour

Dried sweet potato slices, dehulled soybeans, and dried rice were ground with the grain grinder (Model No: GRT-1500B, China) and sieved using a 180 µm sieve to obtain uniform-size flour. Finally, the flour was placed in a clean airtight container.

Formulation of composite flour

The sweet potato flour was kept as the main ingredient and rice flour and soy flour were incorporated for the preparation of composite flour. Composite flour treatments were developed according to the Taguchi experimental design (Mayasti *et al*., 2019). The sweet potato, soy, and rice were composite in the ratio of $\mathbf{T_1}$ 62.5:25:12.5, $\mathbf{T_2}$ 50:30:20, $\mathbf{T_3}$ 41.6:33.3:25, $\mathbf{T_4}$ 60:20:20, $\mathbf{T_5}$ 50:25:25, $\mathbf{T_6}$ 54.5:36.6:9, $\mathbf{T_7}$ 58.3:16.6:25, $\mathbf{T_8}$ 63.6:27.2:9, and $\mathbf{T_9}$ 53.8:30.7:15.3.

Pasta preparation

Pasta for all nine treatments was made using the electric pasta-making machine (Model No: Hamilton Beach 86650, China). Then pasta was dried in the forced air drier (Model No: BOV-V230F, China) at 50 ºC for 12 h. Finally, the samples were sealed and packaged separately using air-tight polypropylene pouches (300 gauge) and stored in a tightly sealed storage cupboard for further analysis. Samples were prepared while maintaining strict hygiene of equipment, utensils, and personnel to prevent any possible microbial contamination.

Preliminary assessment

A preliminary sensory evaluation was done for all the treatments to choose the most preferable treatments. Four samples were selected based on the preliminary sensory evaluation (T_2, T_3, T_4, T_8). A control pasta sample was prepared using wheat flour and used with the selected treatment for further studies.

Proximate analysis

Proximate analysis for moisture, total fat, ash, acid insoluble ash, crude protein, crude fibre, carbohydrates, and calories were calculated and expressed on a dry matter basis for the fresh sweet potato and pasta samples, according to the AOAC (2005) and SLS 420 (2019) standard methods. All the tests were performed in three replicates of each treatment.

Determination of moisture content (%)

The moisture content of fresh sweet potato tubers and pasta was determined by using the oven drying method according to SLS 420 (2019). Five grams of the prepared sample were measured into the previously weighed and dried dish. Then the dish was placed in a drying oven (Model No: 30-1060) at 105 ±2 ºC for 5 h. After 5 h the dish was cooled in a desiccator and the weight was measured. Again, the sample was put in the drying oven at 105 ±2 °C for 30 min. Then again sample was cooled and weighed. The process was continued until the weight remained constant. Finally, moisture content was measured using the following equation.

$$\text{Moisture content (\%)} = \frac{(m_1 - m_2)}{(m_1 - m_0)} \times 100 \quad \ldots(01)$$

m_0= weight of empty dish (g)
m_1 = weight of the dish + sample before drying (g)
m_2 = weight of the dish + sample after drying (g)

Determination of total ash content (%)

The total ash content was determined by using a muffle furnace (Model No: MF1400-30) according to the method prescribed in SLS 420 (2019). Five grams of the prepared sample were measured into the previously weighed and dried crucible. Then the sample was placed in a muffle furnace. The temperature was set to 600 ±2 °C for 5 h, until grey ash was obtained. Thereafter the sample was cooled inside the desiccator and its weight measured. Again, the sample was placed in a muffle furnace for 30 min. The sample was then cooled and weighed again. The process was continued until constant weight was obtained. Finally, the total ash content was measured using the following equation.

$$\text{Total ash content(\%)} = \frac{(m_3 - m_0)}{(m_2 - m_0)} \times 100 \quad \ldots(02)$$

m_0= weight of the empty crucible (g)

m_2 = weight of the crucible with dried sample (g)

m_3 = weight of the crucible with ash (g)

Acid insoluble ash (%)

Acid-insoluble ash determination was done according to SLS 420 (2019). Dilute hydrochloric acid (25 mL of a solution of 12.5 mL conc. HCl topped up to 1000 mL with distilled water) was added into the ash-contained dish (beaker). Previously tested ash samples were used for this test. Then the beaker was covered with a watch glass and placed in the water bath at 95 ±2 °C for 10 min. Thereafter dish was allowed to cool. The content was filtered through the Whatman ashless filter paper No. 42 and the filter paper was thoroughly washed with water until the washings are free from acid. After that filter paper with residue was placed in the drying oven (Model: 30-1060) and the temperature was set to 105 ±2 °C for 3 h. After that the dried sample was placed in a muffle furnace (Model: MF1400-30) at 600 ± 2 °C for 1 h. Thereafter the sample was cooled inside the desiccator and the weight was measured. Again, the sample was placed in the muffle furnace for 30 min, and once more cooled and weighed. The process was continued until constant weight was obtained. Finally, the total acid insoluble ash content was measured using the following equation.

$$\text{Acid insoluble ash content (\%)} = \frac{(m_4 - m_0)}{(m_2 - m_0)} \times 100 \quad \ldots(03)$$

Where,
m_0 = weight of empty dish (g)
m_2 = weight of dish with the dried sample taken for the determination of total ash
m_4 = weight of dish with acid insoluble ash

Crude protein (%)

Triplicate samples of 2 g were placed into a Kjeldahl flask with the catalyst mixture. Distilled water (10 mL) and concentrated sulphuric acid (20 mL) were sequentially added. The mixture was digested at 400 °C for 4 h until it became colourless. The digested solution was allowed to cool, decanted into a volumetric flask, and distilled water was added. An aliquot of 10 mL was pipetted into a Kjeldahl distillation flask and 90 mL of distilled water were added to make up the volume up to 100 mL. Afterward, 20 mL of 40% sodium hydroxide were also added to the mixture, which was distilled into a solution containing 10 mL of 4% boric acid. Three drops of mixed indicators were added to the distillate solution. The distillate, which was light blue in colour, was titrated against 0.1 N hydrochloric acid until the colour changed to pale pink. A blank was also prepared by the same procedure to ensure the accuracy (SLS 420, 2019).

$$\text{Crude protein (\%)} = \frac{V \times N \times M}{Ws \times 10} \times 6.25 \quad \ldots(04)$$

Where,
N = Concentration of acid
V = Volume of acid
M = Molecular Weight of nitrogen (14.007)
Ws = Sample weight
6.25 = Conversion Factor

Fat content (%)

The fat content was determined using Auto-Soxhlet Fat Extractor (Model: FAT-06A) according to the AOAC

2003.05 (AOAC, 2005). For this, an accurate weight (5 g) of the dried sample was taken and put in an extraction thimble and extracted using petroleum ether in Auto-Soxhlet Fat Extractor (Model: FAT-06A) for 6 h. The solvent was evaporated after extraction and the residue dried and weighed in order to determine the percentage composition of crude fat with reference to the initial weight of sample.

Total carbohydrate content (%)

Total carbohydrates were calculated as the difference between 100 and the sum of the moisture, crude protein, fat (lipid), and ash content (Grizotto & Aguirre, 2011).

$$\text{Carbohydrate content}(\%) = [100 - (\text{moisture} + \text{protein} + \text{lipid} + \text{ash})] \quad ...(05)$$

Crude fibre content (%)

The crude fibre content was determined according to AOAC 978.10 method. Approximately 5 g of dried sample was taken and boiled with 200 mL of 0.2 N sulfuric acid for 30 min. The boiled sample was filtered to drain the acid solution, and residue was washed with hot water to remove the acid residue completely. Further, the residue was boiled with 200 mL of 0.2 N sodium hydroxide. Then, the sample was filtered to drain the sodium hydroxide and washed with hot water to remove sodium hydroxide residue completely. The filtrate was collected into a crucible and placed it in an oven (TLPPL 131, India) at 105 °C for 2 h. After that the crucible was placed in a desiccator for 20 min and weighed. Then after, it was placed inside the muffle furnace (MF 1400 –30, India) at 550 °C for 2 h. Finally, the sample was placed in a desiccator for 20 min and the ash was weighed (AOAC, 2005).

$$\text{Fibre} = \frac{\text{weight of the crucible with fibre} - \text{weight of the crucible with ash}}{\text{weight of the original sample}} \times 100 \quad ...(06)$$

Calorie content (kcal/100 g)

Calorie content was determined using a Bomb Calorimeter (IKA C 6000) according to the method of Hopper *et al*., (2023).

Cooking characteristics

Cooking time (min)

The optimum cooking time was determined according to the method elaborated by Giménez *et al*. (2013). First, 25 g of dried pasta was boiled in 250 mL of distilled water. A small portion (3 to 4 strands) of the pasta was removed from the boiling water at 30-second intervals and squeezed between two glass slides. The cooking time of pasta was considered as the time when the white centre core disappeared.

Water absorption capacity (WAC) (%)

The water absorption capacity was determined according to the method of Giménez *et al.* (2013) with slight modifications. Initially, 25 g dried pasta samples were weighed and cooked in 250 mL boiling water for the determined cooking time. Then the cooked samples were drained for 5 min and the cooked pasta was immediately weighed. Water absorption capacity was expressed as the weight difference before and after cooking pasta. The calculation was done using the following equation.

$$\text{WAC}(\%) = \frac{\text{CPW} - \text{DPW}}{\text{DPW}} \times 100 \quad ...(07)$$

Where,

CPW = cooked pasta weight
DPW = dried pasta weight

Solid in gruel (%)

Solid in gruel determination was done according to SLS 420 (2019). Initially, 25 g dried pasta samples were weighed and cooked in 250 mL boiling water until the cooking time was reached. Then the water was collected by draining cooked pasta and the volume of drained water was noted (V). Then 20 mL of the drained water was transferred to an evaporating dish and dried in a drying oven (Model: 30-1060) at 105 ±2 °C for 2 h. Then the dish was cooled in a desiccator and the weight was measured. Again, the sample was kept in the drying oven at 105 ±2 °C for 30 min, then cooled and weighed as before. The process was repeated until a constant weight was obtained. Finally, the solid in the gruel was measured using the following equation.

$$\text{Total solid in gruel} = \frac{(m_1 - m_0)}{5} \times V \quad ...(08)$$

Where,
m_0 = Empty dish weight,
m_1 = Dish with total solids present in 20 mL of gruel
V = Volume in mL

Textural properties

Hardness, adhesiveness, resilience, stringiness, cohesiveness, springiness, gumminess and chewiness were determined using the CT3 Texture analyzer (Model No: MO8-372-GO318). Each sample were tested three times using a TA-PFS-C probe.

Sensory evaluation

The Organoleptic properties (appearance, taste, hardness, stickiness, and overall acceptability) of cooked pasta were evaluation by an untrained panel of thirty people: seventeen women and thirteen men, ages 20 to 55, frequent consumers of pasta and flour-based food, and with some experience of sensory evaluation. All panellists who performed the sensory evaluation ate breakfast 4 h prior. Panellists rinsed their mouths with bottled water between each sample testing. A nine-point hedonic scale, where 1 denotes a strong dislike and 9 denotes a strong liking, was used to assess each of the five attributes. The sensory evaluation was performed in an dedicated areas of Food Technology laboratory with adequate lighting and natural ventilation (Attanzio *et al*., 2019; Olivera & Salvadori, 2011).

Statistical analysis

All the descriptive analysis (table, graph) was done using Microsoft Excel 2013. Also, all the inferential analyses were done using the SPSS software version 26. One-way ANOVA and Tukey's Post Hoc test at the 0.05 significance level were used for analyzing the proximate and physico-chemical tests. In addition, the one-way Friedman test at a 0.05 significance level was used for analyzing sensory data.

RESULTS AND DISCUSSION

Proximate composition of sweet potato

There were no literature reports on the nutrient content of the sweet potato cultivar Carrot Bathala as it has not been officially released by the Horticultural Crop Research and Development Institute (HORDI) in Sri Lanka. The proximate composition of the Carrot Bathala variety on a dry basis is given in Table 1.

Table 1: Proximate composition of Carrot Bathala

Nutrient	Content
Moisture content (sweet potato tuber)	75.9 %
Moisture content- flour (dry basis)	7.58%
Total Ash content (dry basis)	2.64 %
The acid-insoluble ash (dry basis)	0.01 %
Total fat content (dry basis)	0.33 %
Crude protein (dry basis)	4.2 %
Carbohydrate (dry basis)	85.25 %
Crude fibre (dry basis)	7.96 %
Energy (dry basis)	465.9 kcal/100 g

Proximate composition of pasta samples

Moisture content

According to SLS 420 (2019) the maximum acceptable moisture content is 12%, and the moisture content of all treatments were less than 12%. There were no significant differences between treatments (i.e., pasta made from composite flour). However, the moisture content of wheat pasta (control) had significantly ($p < 0.05$) high moisture content (10.9%). Considering the results of moisture content, the moisture content gradually decreased with the increase of soy flour (Table 2). The studies by Farzana & Mohajan (2015), Aremu *et al.,* (2006) and Bolarinwa & Oyesiji (2021) also confirmed that the moisture content of pasta decreases with the increase of soy flour. Compared to wheat flour, soy flour has a higher percentage of the total dry matter and better emulsifying characteristics (Banureka & Mahendran, 2011). Aremu *et al*. (2006) reported that soybean flour may form a complex with water, resulting in a reduced free water availability for analysis.

Protein content

SLS 420 (2019) states that pasta must have a minimum crude protein content of 9%. All the treatments had protein contents greater than 9% and the results were significantly different among the treatments. The highest value for protein was reported at 18.65% in treatment T_3 (SWP 41.6, Soy 33.3, Rice 25) and the lowest value reported in the control sample (11.55%) (Table 2). Farzana & Mohajan (2015) reported that soybean is a high protein legume and an excellent substitute for cereal proteins with lysine restriction, and therefore the incorporation of soy flour increases the significant protein content of the biscuits. The use of soy flour as an economical protein supplement in biscuits, bread, pasta and other cereal products is therefore justified.

Table 2: Proximate composition of pasta samples

Treatment	Flour formulation (%)	Moisture content (%)	Crude protein (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)	Ash (%)	Acid insoluble ash (%)	Energy (kcal/100 g)
Control	100 wheat	10.90 ± 0.08^{a}	11.55 ± 0.07^{e}	1.32 ± 0.29^{b}	0.42 ± 0.20^{b}	74.31 ± 0.33^{a}	1.91 ± 0.05^{c}	0.05 ± 0.02^{a}	468.53 ± 1.51^{c}
T_2	SWP -50 Soy - 30 Rice -20	8.12 ± 0.06^{b}	14.57 ± 0.05^{c}	2.19 ± 0.37^{a}	2.54 ± 0.17^{a}	71.75 ± 0.42^{b}	3.35 ± 0.03^{ab}	0.01 ± 0^{b}	510.30 ± 2.55^{a}
T_3	SWP- 41.6 Soy -33.3 Rice -25	8.03 ± 0.05^{b}	18.65 ± 0.14^{a}	2.31 ± 0.27^{a}	2.39 ± 0.30^{a}	67.62 ± 0.28^{c}	3.38 ± 0.03^{a}	0.02 ± 0.01^{ab}	491.30 ± 1.10^{b}
T_4	SWP-60 Soy-20 Rice- 20	8.1 ± 0.04^{b}	12.67 ± 0.13^{d}	1.96 ± 0.02^{ab}	2.32 ± 0.05^{a}	74.0 ± 0.13^{a}	3.26 ± 0.02^{b}	0.01 ± 0.01^{b}	490.13 ± 2.94^{b}
T_8	SWP– 63.6 Soy-27.2 Rice-9	8.10 ± 0.03^{b}	15.59 ± 0.12^{b}	1.99 ± 0.01^{a}	2.69 ± 0.04^{a}	71.11 ± 0.04^{b}	3.31 ± 0.06^{ab}	0.01 ± 0.01^{b}	469.6 ± 2.49^{c}

Mean ± standard deviation ^{a,b,c,d,e} superscript significantly different at p = 0.05 column wise

Fat content

There is a significant difference in fat values between the control and the other treatments except T_4 (SWP 60, soy 20, rice 20). However, there is no significant difference between the treatments for composite flour pasta. Considering the results for fat content, higher values were confirmed for the composite flour mixtures containing more soy flour. Oluwamukomi *et al*. (2011) state that the addition of 10% soy flour showed a significant increase in fat content of the product concerned. Soybean is one of the protein-rich oil seeds, high in polyunsaturated fats, and containing two essential fatty acids, namely, linoleic acid and α-linolenic acid. Soy flour has a significantly higher fat content than wheat flour (Banureka & Mahendran, 2011).

Fibre content

The results of this study showed a significant difference between controls and other treatments and there was no significant difference between the treatments. The highest and lowest values were recorded in T_8 and control, respectively by 2.69 and 0.42 percent respectively. Progressive increase of fibre content was observed by increasing the proportion of sweet potato flour in the composite flour mixture. The findings of this study were consistent with the findings of Baah *et al.*, (2022). Sweet potato is a low glycaemic food and a high source of dietary fibre (17%) reported by Krishnan *et al*. (2012).

Carbohydrate content

In line with the outcomes of this study, there was no significant difference between the control and the treatment T_4. The treatments T_2 and T_8 are nearly the same. However, there is a significant difference between treatment T_3 and other treatments. The lowest carbohydrate and the highest protein values were in T_3, while the highest carbohydrate content was shown in the control, together with the lowest protein content (Table 2). Increases in soy flour has resulted in the reduction of the carbohydrate content of the composite flour blends, aligning with the finding of Bolarinwa & Oyesiji (2021). Omeire *et al.* (2014) also reported a decrease in the carbohydrate content of noodles from a mixture of wheat, achi, and soya flour, with a rise in the percentage of soya flour in the mixture.

Ash content

SLS 420 (2019) states that the maximum amount of ash in wheat flour is 1%, however, if pasta is made with composite flours and mineral-fortified products, the total amount of ash on a dry basis cannot be more than 4%. In this case, wheat pasta (control) was not within the limit, and the ash content of composite flour products, did not exceed the standard limit (Table 2). The ash content of all the treatments was significantly higher than that of the control treatment. There was also a significant difference between T_3 (SWP 41.6, Soy 33.3, Rice 25) and T_4 (SWP 60, Soy 20, Rice 20) but no significant difference between the other treatments (T_2 and T_8). The ash content of all samples of sweet potato flour was significantly high than that of wheat flour, due to the high mineral content of the root and tubers (Yadav *et al*., 2014).

Acid-insoluble ash

The acid-insoluble ash content of the treatments was below the limit as per SLS 420 (2019). However, there is a significant difference between the control treatment and other treatments except for T_3 (Table 2). Other treatments showed no significant differences among them. It was reported that the acid-insoluble ash content is likely to be higher because of the possibility of chipping and percolating of the fine stone particles into the atta (whole wheat) during the grinding process (Inamdar *et al*., 2015).

Cooking behaviours of cooked pasta

Table 3: Cooking characteristics of pasta samples

Treatment	Flour Formulation (%)	Cooking time (Min)	Water absorption capacity (%)	Solid in gruel (%)
Control	100 wheat	13.1 ± 0.2^a	113.87 ± 3.70^a	8.50 ± 0.19^b
T_2	SWP -50 Soy - 30 Rice -20	7.1 ± 0.2^b	91.35 ± 2.89^b	11.25 ± 0.18^a
T_3	SWP- 41.6 Soy -33.3 Rice -25	7.0 ± 0^b	93.10 ± 1.67^b	11.12 ± 0.04^a
T_4	SWP-60 Soy-20 Rice- 20	7.0 ± 0^b	92.62 ± 2.75^b	11.10 ± 0.06^a
T_8	SWP– 63.6 Soy-27.2 Rice-9	7.1 ± 0.2^b	94.20 ± 3.02^b	11.20 ± 0.11^a

Mean ± standard deviation ^{a,b} superscript significantly different at p = 0.05 column wise

Cooking time

The cooking time of the control sample was significantly ($p < 0.05$) longer (13 min) than that of the composite flour pasta (7 min) as detailed in Table 3, possibly because the dietary fibre constituent in orange-fleshed sweet potato flour tends to disrupt the physical structure of the pasta, reducing the cooking time and limiting its ability to expand compared to commercial pasta (Wang *et al.,* 2019).

Water absorption capacity

Significantly higher water absorption capacity ($p < 0.05$) was indicated in control sample (113) than in composite flour pasta (Table 3). Petitot *et al.* (2010) reported durum wheat proteins are mainly composed of glutenin and gliadins that form intra and intermolecular disulphide bonds during processing. This leads to the development of a three-dimensional gluten network responsible for the unique textural properties of pasta.

Solid in gruel content

Based on the results, the solid in gruel content increased significantly ($p < 0.05$) in composite pasta treatments than in the control sample. According to the finding of Rayas-Duarte *et al.* (1996) the non-gluten components diluted the strength of the gluten and lead to a weakened structure of spaghetti. Hence, the leaching of more solid substances from the spaghetti into boiling water increased the solid gruel content. Furthermore, pasta samples composited with orange flesh sweet potato flour may have a higher cooking loss due to the fibre content of the orange flesh sweet potato flour (Baah *et al*., 2022; Foschia *et al.*, 2015).

Textural characters of pasta

Table 4: Textural characters of cooked pasta

Treatment	Flour formulation (%)	Hardness (g)	Adhesiveness (mJ)	Resilience	Cohesiveness	Springiness (mm)	Gumminess (g)	Chewiness (mJ)
Control	100 wheat	114.16 ± 23.62^{b}	0 ± 0^{a}	0.49 ± 0.04^{ab}	1.06 ± 0.19^{a}	2.35 ± 0.25^{a}	117.00 ± 26.28^{b}	2.73 ± 0.83^{b}
T_2	SWP -50 Soy - 30 Rice -20	327.5 ± 50.18^{a}	0 ± 0^{a}	0.41 ±0.03^{b}	0.94 ± 0.10^{a}	2.27 ± 0.14^{a}	243.30 ± 15.04^{a}	6.96 ± 2.05^{ab}
T_3	SWP- 41.6 Soy -33.3 Rice -25	328.33 ± 62.26^{a}	0.17 ± 0.29^{a}	0.58 ± 0.02^{a}	0.92 ± 0.22^{a}	2.67 ± 0.54^{a}	311.00 ± 73.08^{a}	12.10 ± 7.21^{a}
T_4	SWP-60 Soy-20 Rice- 20	256.66 ± 12.33^{a}	0 ± 0^{a}	0.46 ± 0.05^{ab}	0.96 ± 0.12^{a}	2.47 ± 0.66^{a}	226.66 ± 42.19^{a}	4.46 ± 1.22^{ab}
T_8	SWP– 63.6 Soy-27.2 Rice-9	245.83 ± 62.06^{a}	0 ± 0^{a}	0.40 ± 0.08^{b}	0.95 ± 0.02^{a}	2.40 ± 0.45^{a}	205.66 ± 13.20^{ab}	4.20 ± 0.20^{ab}

Mean ± standard deviation ^{a,b} superscript significantly different at p = 0.05 in column wise

Textural characteristics of the composite flour pasta and control sample are given in Table 4. Based on the results, there is no significant difference in adhesiveness, cohesiveness, or springiness between the treatment and control. However, the hardness of cooked pasta significantly differed from the control treatment. The highest value of hardness was found in the T3 sample (328.33 g). According to the study of Jiao *et al*. (2020), the hardness of rice flour was influenced by its amylose content and retrogradation rate . Furthermore, Kraithong & Rawdkuen (2021) explored how high amylose and protein contents promote higher values of hardness, cohesiveness, springiness, and chewiness. Except for treatment T_8 the gumminess of cooked pasta significantly differed from the control treatment. The results showed that gumminess and chewiness of composite pasta decreased with increasing sweet potato flour content. Santiago *et al*. (2016) revealed that the hardness, gumminess and chewiness of the purple sweet potato flour pasta was significantly lower than that of the control (wheat pasta). Also, a higher value of chewiness was recorded in the T3 sample with value of 12.1 mJ. The studies by Xiao *et al*. (2022) and Fari *et al*. (2011) reported that the amount of grain amylose content is an important factor in determining the quality of rice noodles, and higher hardness and chewiness of cooked rice noodles was generally associated with higher amylose content in the rice grain.

Sensory evaluation

Table 5: Sensory evaluation of pasta samples

Treatment	Formulation	Appearance	Taste	Hardness	Stickiness	Overall acceptability
Control	100 wheat	6.46 ± 1.67^{ab}	5.40 ± 1.83^{b}	6.03 ± 1.80^{ab}	5.57 ± 2.04^{b}	5.67 ± 1.80^{b}
T_2	SWP -50 Soy - 30 Rice -20	7.13 ± 1.07^{a}	7.36 ± 1.18^{a}	7.07 ± 0.98^{a}	6.83 ± 1.08^{a}	7.47 ± 1.10^{a}
T_3	SWP- 41.6 Soy -33.3 Rice -25	5.53 ± 1.79^{b}	6.20 ± 1.73^{b}	6.10 ± 1.39^{b}	5.93 ± 1.31^{b}	6.23 ± 1.54^{b}
T_4	SWP-60 Soy-20 Rice- 20	7.13 ± 1.19^{a}	6.43 ± 1.92^{b}	6.47 ± 1.45^{ab}	6.30 ± 1.66^{ab}	6.57 ± 1.40^{b}
T_8	SWP– 63.6 Soy-27.2 Rice-9	6.60 ± 1.30^{a}	6.10 ± 1.42^{b}	6.20 ± 1.47^{ab}	$6.27 \pm 1 .11^{ab}$	5.93 ± 1.36^{b}

Mean ± standard deviation ^{a,b} superscript significantly different at p = 0.05 column wise

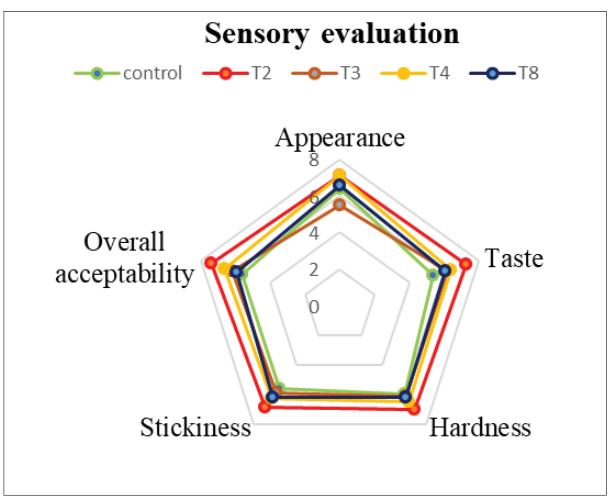

Figure 1: Spider diagram for sensory evaluation of pasta samples

The sensory results showed that the treatment T_2 and T_4 had the greatest appearance gains (Figure 1). Additionally, T_3 had the lowest appearance. According to the taste results, treatment T_2 was preferred by the majority of panellists, while control showed the least amount of preference. Most panellists were interested in treatment T_2 when comparing the results of hardness and had the most appropriate hardness of pasta according to the participant's preferences. For the stickiness, most participants preferred treatment T_2 with least preference for the control. Considering all the attributes, the highest value for overall acceptability was obtained for Treatment T_2. The least acceptability was obtained in the control sample. Overall, most of the panellists preferred the Treatment T_2 composite flour blend (sweet potato 50, soy 30, rice 20) with the control (wheat only) gaining least preference (Table 5).

CONCLUSION

A process flow and quality assessment of pasta made from a composite flour of sweet potato, soy, and rice were developed. The formulation T_2 (sweet potato 50%, soy 30%, and rice 20%) has been shown to have better results in all sensory characteristics, nutritional composition and acceptable textural properties. However, the control sample obtained the best results in terms of cooking behaviour. Low cooking behaviour was observed in all composite flour pasta treatments compared to wheat pasta with the cooking time of 7 min, water absorption between 91 – 94%, and solid in gruel (cooking loss) with 11%. The highest levels of hardness, chewiness, and gumminess are observed in pasta made from composite flour. In addition, pasta made from composite flour fulfils the requirement of the SLS 420 (2019) pasta product specification except for solid in gruel. In addition, the pasta made from composite flour had a higher nutritional value and better sensory characteristics. Therefore, the T_2 (sweet potato - 50, soy - 30, rice - 20) formulation was selected as the best treatment.

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