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Original Paper

Utilization of Cassava Flour and the Addition of Gluten for the Preparation of Noodles

Adit Sangroula[1], Kishor Rai[2], Priti Acharya[3], Nepoliyan Ghimire[1], Girija Sherma[1], Saru Giri[4], Sabina Khadka[3], Himalaya Ghimire[4] and Ramila Dahal[3]*

1) Central Department of Food Technology, Tribhuvan University, Dharan, Nepal
2) Mahendra Multiple Campus, Tribhuvan University, Dharan, Nepal
3) Nilgiri College, Tribhuvan University, Itahari, Nepal
4) Tribhuvan University, Dharan Multiple Campus, Dharan, Nepal
***)** *Corresponding author:* *kishorchamling1989@gmail.com*

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***Abstract*— The aim of the study was to utilize cassava flour in the preparation of noodles. Wheat flour, cassava flour, and gluten were mixed in calculated amounts to produce noodles in the ratio (cassava flour:wheat flour:gluten) of 0:100:0, 92.5:0:7.5, 23.125:65.625:11.25, 42.5:42.5:15, 23.125:73.125:3.75, 65.625:23.125:11.25, 50:50:0, 0:92.5:7.5, 0:85:15, and 85:0:15 and named as samples A, B, C, D, E, F, G, H, I, and J, respectively. The yield of cassava flour was found to be 43.1%. Sensory comparison elected sample C, containing 65.625% wheat flour, 23.125% cassava flour, and 11.25% gluten, as the best. The moisture content, protein, fat, ash, crude fiber, carbohydrate, and cooking time of sample C were found to be 9.37±0.31%, 18.70±0.14%, 1.20±0.04%, 1.26±0.01%, 1.80±0.03%, 77.04±0.29%, and 6±0.3 min, respectively. When compared with wheat flour noodles, crude fiber and protein were found to be greater. Higher water absorption and volumetric expansion with low cooking loss were found in cassava flour-used noodles. Statistical analysis (ANOVA) at the 5% level of significance ($p<0.005$) shows a significant difference in all attributes. The cyanide content of the cassava flour was found to be 5.63±0.20 mg/kg, which is within a safe level, i.e., 10 mg of hydrogen cyanide per kg of dry weight set by the Food and Agriculture Organization and the World Health Organization.**

Keywords*— *Cassava, composite flour, cyanide content, sensory evaluation and proximate analysis

I. Introduction

Noodles are one of the oldest foods which forms an integral part of the diet of millions in China, Indonesia, Japan and other countries worldwide [1]. As per the World Instant Noodles Association [2], global demand for the product is estimated to be 121,200 million servings [2]. The noodle is originally made from durum wheat with a high protein content and is characterized by thin strips cut from low moisture sheeted dough made of water, common salt, alkaline salts, and wheat flour. The dough is sheeted multiple times and pressed between combining rollers during the noodle-making process before being cut into strips [1]. Noodles can be made using hard, intermediate, or soft wheat flours. Whether alkaline salt is used or not, noodles are divided into two categories: white salted and yellow alkaline [3].Noodles can be served in a number of ways, such as fried, steamed, dry, half-boiled, and boiling [4]. They are convenient, simple to prepare, fast-cooking, relatively cheaper, and have a long shelf life [5]. Good-quality noodles are generally characterized by their firmness, reduced stickiness, and minimal sogginess after the cooking process. The texture of a product is primarily influenced by the structural composition of starches, gluten, additional proteins (depending on the starch source), and other ingredients. The quality of finished noodles is generally based on appearance and texture [6].

Cassava flour (CF) refers to the dry, fibrous, and free-flowing particulate product obtained from cassava roots. Cassava flour is either prepared from milled dried chips or wet mash. Mashing of cassava root can be achieved by doing some processing such as grating, pounding, or milling of peeled roots. The prepared mash may either be fermented or unfermented. A bland, odorless, white or off-white particulate product known as high-quality cassava flour is produced when the unfermented mash is dried and ground [7, 8]. Furthermore, the inclusion of cassava can enhance the suitability of crops as industrial raw materials. Cassava serves as a valuable source of carbohydrates, making it well-suited for noodle production, and it also contains minerals that can augment the nutritional value of noodles [9]. A major factor limiting the food value of cassava is the presence of cyanogenic glucosides (linamarin and lotaustralin), which liberate acetonecyanohydrin and hydrogen cyanide upon hydrolysis by the endogenous enzyme linamarase. This cyanogenic compound must be removed prior to the cassava being used as a food ingredient [10]. Processing has been recognized as the most efficient way of controlling cassava cyanogens in the short term. A wide diversity of processing methods is used in cassava-consuming communities. These include peeling and slicing fresh tubers, followed by soaking, boiling, baking, steaming, sun drying, deep frying, fermentation, grating, or pounding, followed by drying or roasting. Most of these processing methods are effective in reducing cyanogenic glycoside (CNG) content [11-13]. When cassava tubers are sliced into small pieces and boiled in water, approximately 80% of CNG is eliminated. Sun-drying cassava chips with a thickness of 10 mm also leads to an 80% reduction in CNG. Processes like baking, steaming, and frying incur minimal loss of CNG (around 20%), attributed to the deactivation of linamarase and the stability of linamarin at elevated temperatures. The method of grating or pounding followed by sun-drying proves to be the most effective, promoting enzyme reactions and achieving a removal of 95–99% of CNG [14].

Nepal was ranked in the 13th position on the world noodle demand ranking in 2022, with 1,650 million servings. The demand for noodles in Nepal has been predicted to increase with population growth [2]. Agriculture is the primary occupation of people in Nepal [15]. A wide range of agroecological and climatic factors make Nepal a wonderful place to produce quality agricultural products [16]. In regions where maize and other crops will not grow or produce as well, cassava can grow and yield in large amounts. It can be grown on low-nutrient soils and can withstand drought. Cassava has a high potential for energy production per unit area of land and has very flexible management requirements. Due to its lack of a clear maturity point, cassava has long been used as a crop for food security and famine reserves. However, despite its high production, cassava is not used enough in Nepal. Fresh cassava doesn't usually have a market. A large portion of this opportunity arises from the possibility of import substitution or from the emergence of new and expanding industries that could make use of cassava and cassava products. The need to develop noodles from indigenous crops is imperative. Previous research has demonstrated the feasibility of employing non-wheat flour sources in the manufacturing of noodles. Buckwheat flour [17], cassava flour [10], corn grit and cassava flour [18], cocoyam, plantains, yam, cassava, and sweet potato flour [5], and starches from potato and sweet potato [19], corn flour, and tapioca flour [20] have been used in noodle production. But these mentioned studies lacked studies of cooking time, cooking loss, water absorption capacity, and cyanide content of noodles, which are covered in our study. The objectives of this study were to determine the chemical analysis of raw wheat flour and cassava flour, the sensory properties of cassava flour-added noodles, and the physiochemical analysis of an optimized product.

II. Materials And Methods

A. Materials

Wheat flour, cassava tubers (*Manihot esculenta*), and salt named "iodized salt" were brought from the local market in Dharan. Gluten named 'Vital Wheat Gluten' (Batch No. GRF181822) was collected from SG Nepal Pvt. Ltd. Other materials were used from the laboratory stock.

Materials for the analysis of nutrient content include cupric sulfate ($CuSO_45H_2O$), potassium sulfate (K_2SO_4), sodium hydroxide pellets (NaOH), hydrochloric acid (HCL), concentrated sulfuric acid solution (H_2SO_4), ammonium hydroxide (NH_4OH), potassium iodide (KI), silver nitrate ($AgNO_3$) from Thermo Fisher Scientific India Pvt. Ltd., boric acid solution (H_3BO_3) (Merck specilities Pvt. Ltd., India), petroleum ether (C6H14) (Boiling point: 60-800 ℃, Specific Density: 0.68, Himedia Laboratories Pvt. Ltd., India), indicator methyl red (MR)/bromocresol green (BCG) solution and phenolpthalein indicator from Oxford Lab Fine Chemical LLP, India, and distilled water.

Stainless steel basins, knives, cutting boards, spoons, and boiling pots. While the equipment used for the analysis of nutrient content includes petri plate, hot air oven (Navyug Udyog, Haryana, India), calibrated analytical balances (Model: PH3203CH No: 13020123, Capacity: 320g, Precision: ±0.001g and Model: HZT-A500, Max. Capacity: 500g, Min. Capacity: 10g, India), desiccators containing desiccant, muffle furnace (Relitech, Model-MF-1, Wattage-2KW, India), electric heaters, electronic Grinder (Yasoda, India), multi-Thermometer (KT 201270865, Mextech), water bath, porcelain cups, Kjeldahl digestion (Jain Laboratory Glassware co., India, Power-50HZ), complete Soxhlet apparatus (Religlass, Model-SEU-6M, Wattage-1200W, Jain Laboratory Glassware co., India), Suction pump (Indian Company), kjeldahl distillation apparatus, 10mL burette, buchner filter assembly and noodles machine (Indian company) was taken from Dharan Multiple Campus.

B. Methods

1) Preparation of cassava flour

The grinded flour was passed through the sieve size of 150µ. After sieving, the cassava flour was packed in a polythene bag and stored at room temperature [21]. The preparation of cassava flour is shown in Fig. 1.

2) Preparation of cassava-based wheat noodles

Noodles were prepared by simple modifications to the process as described by Shelke, Dick [22]. Design-Expert® v10.01 was used to design the study. The noodles were prepared as the recipe formulation was done, and codes A, B, C, D, E, F, G, H, I, and J were given to each recipe. The ingredient and proportion will be as shown in Table 1.

The standard formula for this study consists of 100 parts composite flour, 32 parts moisture content in the final dough, 1 part sodium carbonate, and 1.5 parts salt. The amount of water to be added is calculated by using the following formula:

Amount of water required to dose (Gw) = Gm (Wd-Wf) / (100-Wd)

Where, Gw = amount of water required for dosing

Gm = dosing of the flour in kg

Wd = moisture content of dough

Wf = moisture content of flour

The prepared dough was mixed thoroughly for about 30 minutes. Then the dough was left for 30 minutes to stiffen. The dough was transferred to the noodle-making machine. The dough mixture was pressed into the roller of the noodle machine. The gap between the rollers was set at 3.8 mm. The mixed dough was passed through the roller at a low speed. The sheet was folded in half and passed between the roller gaps at 5.68 mm. The cycle was repeated six times. The dough sheet was then gradually reduced in thickness without folding by decreasing the roller gap to 4 mm, and the sheet was then passed through the cutter rolls to be slit into strands. A noodle strip was hanged on bamboo sticks in a closed room at room temperature for about 24 hours, which acts as a sweating period. The noodles were sundried by hanging them on the sticks at a safe moisture level. The final noodles were weighted and packed in a polyethylene bag [22]. It was carried out at the Dharan Multiple Campus. The method for the preparation of cassava-based wheat noodles is given in Fig. 2.

TABLE 1: RECIPE FORMULATION FOR THE PREPARATION OF NOODLE

Ingredients	Wheat flour (Parts)	Cassava flour (Parts)	Gluten (Parts)	Water (Parts)	Sodium carbonate (Parts)	Salt (Parts)
A	100	0	0	19.7	1	1.5
B	0	92.5	7.5	22.31	1	1.5
C	65.625	23.125	11.25	20.84	1	1.5
D	42.5	42.5	15	21.54	1	1.5
E	73.125	23.125	3.75	20.51	1	1.5
F	23.125	65.625	11.25	22.02	1	1.5
G	50	50	0	21.1	1	1.5
H	92.5	0	7.5	20.53	1	1.5
I	85	0	15	20.35	1	1.5
J	0	85	15	22.725	1	1.5

Cassava tubers
↓
Washing with tap water
↓
Trimming and sorting with knifes
↓
Peeling with knifes
↓
Dipping into 2% salt solution for 30 minutes at 29^{o}C
↓
Slices of 3-5 mm thick were made
↓
Dipping into 0.5% Potassium metabisulphite (KMS) and 0.5% citric acid solution for 30 minutes
↓
Draining the solution
↓
Blanched peeled cassava slices
↓
Oven drying of cassava slices at 60^{o}C till brittle
↓
Grinding
↓
Sieving with sieve size of 150 µ
↓
packaging of cassava flour in polythene bag

Fig. 1 Preparation of cassava flour from cassava tubers

Source:[21]

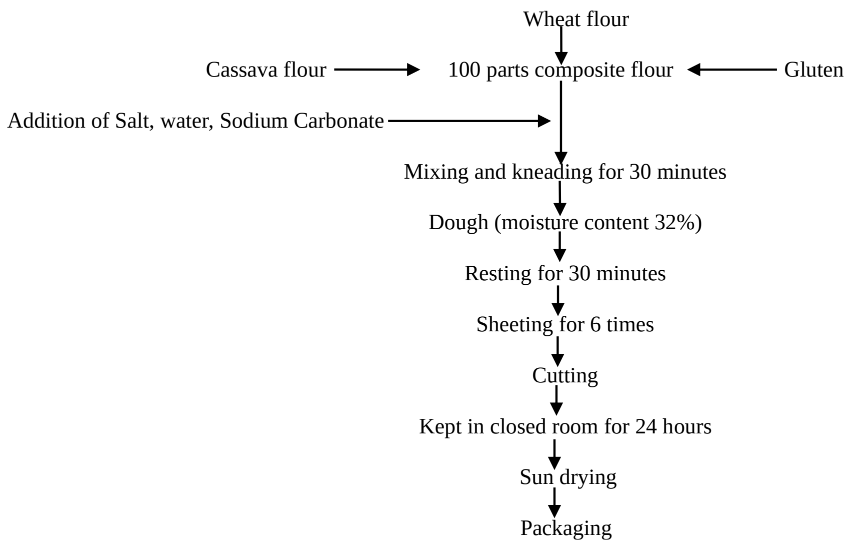

Fig. 2 Preparation of cassava-based wheat noodles

Source: [22]

III. ANALYTICAL PROCEDURE

A. Proximate analysis of wheat flour, cassava flour, and noodle products

Determination of moisture content

The moisture content was determined using the hot-air oven method [23]. A finely powered five-gram sample (W) was taken from a Petri dish of known weight. The petri dish containing sample (W1) was then placed in a hot air oven set to 100±5 °C and dried until a constant weight was observed (W2). The difference in the sample weight was interpreted as the presence of water in the sample. The experiment was performed in triplicate.

$$\text{Moisture content (\%)} = \frac{(W1-W2)}{W}\times 100$$

Determination of crude fat content

The crude fat content of the samples was determined by the solvent extraction method using a Soxhlet apparatus and petroleum ether solvent [23]. Five grams of sample (W) were taken in triplicate and placed in a thimble. The thimble was covered with cotton wool. An empty, dry, and clean round flask (W1) with a known weight was connected to the siphoning apparatus. The thimble containing the sample was placed in the siphoning apparatus, and 200 ml of petroleum ether (with a boiling point of 60–80 °C) were added. Then the condenser was connected to the siphoning apparatus, and the heater was switched on, and extraction was applied for 4-5 hours. After the extraction was completed, the petroleum ether was evaporated from the round flask. The round flask containing the extracted fat (W2) was weighed, and the fat content as a percentage was calculated according to the following equation:

$$\text{Crude fat content (\%)} = \frac{(W2-W1)}{W}\times 100$$

Determination of crude protein content

The protein content was determined using a two-gram sample. The total nitrogen content was measured employing the micro-Kjeldahl method [24]. To convert the nitrogen content to crude protein, a conversion factor of 6.25 was applied.

$$\text{Nitrogen (\%, wet basis)} = \frac{(\text{Sample titer}-\text{Blank titer})\text{ml} \times \text{N of HCL} \times 14 \times 100 \times 100}{\text{Aliquot (ml)} \times \text{Wt.of sample (g)} \times 1000}$$

$$\text{Nitrogen (\%, dry basis)} = \text{Nitrogen (\%, wet basis)} \times \frac{100}{\text{Dry matter}}$$

$$\text{Protein (\%, dry basis)} = \text{Nitrogen (\%, dry basis)} \times 6.25$$

Determination of crude fiber content

The crude fiber content of the samples was determined using the chemical digestion method [23]. Crude fiber was determined on a three-gram defatted dried sample (W), preferably from crude fat determination. Digestion was carried out by refluxing the sample for 30 minutes in 1.25% H_2SO_4, and the acid-digestible residue was placed in a filtering funnel containing muslin cloth and washed repeatedly with hot distillation water till it was acid-free (the filtrate was tested with blue litmus paper; if blue litmus paper resists the same color, then the residue was acid-free). The acid-digestible residue was then subjected to 1.25% NaOH digestion for 30 minutes, and after completion of digestion, the alkali-digestible residue was transferred into a filtering funnel containing muslin cloth and washed repeatedly with hot distillation water till it was alkali-free (the filtrate was tested with red litmus paper; if the same litmus paper resists the same color, then the residue was alkali-free). Finally, alkali-free residue was transferred carefully to a clean silica crucible, which was dried in a hot air oven at 100 °C to bone-dryness. After cooling the crucible along with the residue in the desiccator (W2), a weigh was taken. The same weighted sample was placed in a muffle furnace at 450–500 °C until all the carbonaceous materials were burned out. This usually took about 30 minutes, cooled in a desiccator, and then weighted the crucible along with ash (W1).

Crude fiber content (%) = $\frac{(W2-W1)}{W}\times100$

Determination of total ash

The total ash content of the sample was determined using a muffle furnace [24]. Two grams (W2) of the sample were weighed by difference into a pre-dried, pre-weighed crucible (W1). Then the sample was incinerated in a furnace at 500 °C for 3–4 hours. The temperature of the furnace was decreased to 180 °C and the crucibles were transferred into a desiccator, cooled for 15–30 minutes, and weighed (W3). The ash content was calculated by the following method:

Ash (%) = $\frac{(W3-W1)}{(W2-W1)}\times100$

Determination of carbohydrates

Total carbohydrate was determined by the difference method [25].

Total Carbohydrate (%) = 100 – (fat % + protein % + ash % + moisture % + crude fiber %)

B. Analysis of flour

Gluten content of wheat flour

Gluten was obtained by weighing 25 grams of flour. Water was added to the flour and mixed to obtain a ball of flour. The ball was immersed in water and kept for an hour. Then the starch from the flour was washed by hand. The completion of starch removal was insured by an iodine test. The starch-free ball was pressed, dried as much as possible, and weighed. A gluten ball was dried at 100 °C for 24 hours in an oven and weighed. The gluten percentage was calculated as described below [26].

Wheat gluten (%) = $\frac{\text{Weight of gluten}}{\text{Weight of sample}}\times100$

Cyanide content of cassava flour

The cyanide content of cassava flour was determined by the alkaline titration method [27]. A 10–20-gram test portion of cassava flour was taken in an 800 ml Kjeldahl flask. To the flask, about 200 ml of water was added, and the flask, along with the test portion, was let stand for 2-4 hours for autolysis. Then the flask was completely connected to the distillation assembly. About 150–160 ml of distillate were collected in a sodium hydroxide (NaOH) solution (0.5 grams in 20 ml of HP) and diluted to a definite volume. To 100 ml of distillate (it is preferable to dilute about 250 ml, and from which 100 ml of distillate was taken), 8 ml of 6 M NH_4OH and 2 ml of 5% KI solution were taken and titrated with 0.02 M $AgNO_3$ using a micro burette until the end point (faint but permanent turbidity). 1 ml 0.02 M $AgNO_3$ = 1.08 mg HCN (Ag equivalent to 2 CN)

C. Cooking test of noodle products

Cooking loss

Loss of solids during cooking was determined by collecting the cooking water following drainage of the noodles for the total organic matter value test; 5 ml of cooking water was drained in an oven at 105 °C. The dried residue was weighed, and the results were expressed as a proportion of the uncooked noodles [28].

Water absorption test

Six separate 10-gram samples of noodles were cooked in 2000 ml of boiling distilled water for 2, 4, 5, 6, 7, and 8 minutes, respectively. The sample was immersed in a stainless-steel strainer. At the end of cooking, the samples were removed from the strainers, rapidly blotted dry, and accurately weighed. Three determinations were made for each sample. Cooked noodle water absorption was calculated from the cooked noodle weight [28].

Cooking time

In this method, five grams of sample in 30 ml of water were taken from each Petri plate and cooked for 5, 8, 10, 12, and 15 minutes, respectively. The suitable cooking time has been determined. To determine the cooking time, the noodles were cooked with a spoon, and the exposed part was observed. It was cooked until there were uncooked specks on the cut exposed part [29].

D. Sensory evaluation

Noodles made from cassava-wheat flour were evaluated by 20 panelists who regularly patronize noodles or pasta and have previous experience in sensory evaluation. The panelists evaluated the products based on how much they liked their appearance, aroma, taste, texture, and overall acceptability. A 9-point hedonic scale (1 representing dislike extremely and 9 representing like extremely) was used for the evaluation [24, 30]. Each panelist was provided with ten coded samples and a sheet of sensory evaluation cards.

E. Statistical analysis

The analyses were carried out in triplicate. Data on the sensory quality of noodles made from cassava-wheat flour with gluten and wheat flour only were statistically processed by Genstat Release v12 for a two-way analysis of variance (ANOVA). The means of the data were compared using the LSD (least significance difference) method at a level of significance of 5% [31].

IV. RESULT AND DISCUSSION

A. Analysis of raw materials

Cassava flour and wheat flour were the major raw materials. The yield of cassava flour was found to be 43.1%. The yield can be increased by reducing the loss in processing [32]. The proximate composition is shown in Table 2.

The moisture, protein, fat, carbohydrate, crude fiber, and ash of the wheat flour and cassava flour found from analysis are shown in Table 2. The moisture, fat, total ash, protein, crude fiber, carbohydrate, and gluten content of wheat flour were found to be 12.3%, 1.06%, 0.78%, 13.27%, 0.41%, 84.48%, and 9.11%, respectively. These values were almost similar to those of Dahal, Dangal [33], who reported 12.55% moisture, 9.70% crude protein, 1.50% crude fat, 0.42% crude fiber, 0.51% total ash, 9.08% gluten and 73.35% carbohydrate. Similarly, Oyeyinka and Bassey [34] reported the moisture content (8.58%–10.16%), fat content (1.36%–1.56%), ash content (0.87%–1.10%), protein content (10.82%–12.75%), crude fiber (0.47–0.61%), carbohydrates (75.24%–77.40%), and gluten content (10.10%–11.20%) in four brands of wheat flour.

Moisture, protein, crude fiber, fat, total ash, and carbohydrate content of cassava flour were found to be 9.5%, 1.62%, 2.68%, 0.66%, 1.7%, and 93.29%, respectively. The obtained results were also similar to those of Obadina, Oyewole [18], which reported moisture (14.50%), protein (0.50%), ash content (1.49%), crude fiber (1.00%), fat (0.10%), and carbohydrate (82.41%). The high amount of crude fiber in cassava flour may be due to the incomplete removal of non-starchy polysaccharide (NSP). The sorting and peeling are done manually, due to which incomplete removal of the central portion of cassava root results in a high crude fiber amount [35].

The safe levels for cyanogen in cassava food products set by [36] are 10 ppm, or 10 mg/kg dry weight. The cyanide content of cassava flour was found to be 5.63 mg/kg. Based on the results, the cyanide level of the investigated cassava flour falls within the acceptable limits of 10 mg HCN equivalent/kg dry weight recommended by FAO/WHO for safe cassava products. Fukushima, Nicoletti [37] conducted research on the cyanide levels present in commercially available cassava flours in Brazil. He reported cyanide content as artisan toasted cassava flour: 15 mg/500g, sweet cassava starch: 32.5 mg/500g, artisan dried cassava flour: 37.5 mg/500g, "bijuzada" cassava flour: 60 mg/500g, industrialized toasted cassava flour: 115 mg/500g, industrialized raw cassava flour: 140 mg/500g, and wet cassava flour: 225 mg/500g. The cyanide concentration in cassava can range from approximately 75 to 350 ppm (parts per million), with the potential to exceed 1000 ppm or even higher. This variability is influenced by factors such as the cassava variety, plant age, soil conditions, fertilizer application, weather, and various other contributing factors [38-40].

TABLE II. COMPOSITION OF WHEAT FLOUR AND CASSAVA FLOUR

Parameters	Wheat flour	Cassava flour
Moisture	12.3±0.07	9.50±0.30
Protein (% db)	13.27±0.37	1.62±0.31
Fat (% db)	1.06±0.06	0.66±0.20
Total ash (% db)	0.78±0.03	1.7±0.21
Crude fiber (% db)	0.41±0.05	2.68±0.31
Carbohydrate (% db)	84.48±0.32	93.29±0.83
Cyanide content (% db)	-	5.63±0.20 mg/kg
Gluten content (% db)	9.11±0.30	-

The values in the table are the arithmetic mean of a triplicate analysis. Figures after ± indicate the standard deviation.

B. Sensory evaluation of noodles

Appearance

The appearance of the noodles was basically graded on the basis of color and shape. The obtained mean values are represented as a bar diagram in Figure 3. The mean sensory scores for appearance were 8.60, 6.00, 8.20, 7.00, 7.20, 7.80, 5.80, 7.60, 8.00, and 5.40, respectively, for samples A, B, C, D, E, F, G, H, I, and J. The mean sensory score for the appearance of samples A and C is the highest, while the lowest is for sample J. One important quality index for noodles that affects consumer decisions to buy them is their visual appearance. Akonor, Tortoe [5] showed that panelists generally rated the appearance of noodles made from cocoyam, plantains, and sweet potatoes relatively lower than cassava and yam flour noodles. Whereas increasing amounts of cassava or yam resulted in a higher rating for appearance, changes in the proportion of the other flours did not significantly ($p > 0.05$) affect these organoleptic indices. The observed trend for appearance and color may be attributed to the fact that noodles made from cassava and yam flours appeared brighter compared to noodles made from the other flours [5]. However, the appearance of sample A (the control sample) is high due to the panelists regular vision of the marketed noodles (i.e., wheat flour only), and that of sample C is also high due to the shininess of the noodles. The appearance of sample J is the lowest due to the poor structure of the noodles.

Texture

The mean sensory scores for texture were 8.00, 6.60, 8.40, 7.20, 7.20, 7.00, 6.00, 6.40, 6.60, and 5.80, respectively, for samples A, B, C, D, E, F, G, H, I, and J. The obtained mean values are represented as a bar diagram in Figure 3. The mean sensory score for texture in sample C is the highest, while the lowest is in sample J. It is due to the rubbery texture and also to the biting properties of cassava-incorporated noodles. Rosemond, Adelaide [41] showed that the pasta made from 25% wheat flour and 75% cassava flour was generally poor in consistency as compared to the pasta made from the 75% wheat flour and 25% cassava flour composition. He also showed that high-quality cassava flour can substitute up to 30% of wheat flour in sweet dough biscuits and 40% in hard dough biscuits without detectable changes in texture compared to the 100% wheat flour control. Cassava flour proved effective as a partial substitute for imported wheat flour in biscuits or other pasta products [41].

Aroma

The mean sensory scores for aroma were 8.20, 6.20, 8.60, 7.20, 7.60, 7.20, 5.40, 7.20, 6.80, and 5.60, respectively, for samples A, B, C, D, E, F, G, H, I, and J. The obtained mean values are represented as a bar diagram in Figure 3. The mean sensory score for aroma in sample C is the highest, while the lowest is in sample G. It may be due to the partial addition of cassava flour, which makes a perfect blend with wheat flour to give a good aroma, and the lowest of sample G is due to an unpleasant aroma [5, 41, 42].

Taste
The mean sensory scores for taste were 8.00, 6.40, 9.00, 7.00, 7.20, 7.20, 5.20, 6.40, 7.00, and 5.40, respectively, for samples A, B, C, D, E, F, G, H, I, and J. The obtained mean values are represented as a bar diagram in Figure 3. The mean sensory score for taste in sample C is the highest, while the lowest is in sample G. It is due to the pleasant taste of cassava flour and the unique taste of cassava flour [5, 41, 42].

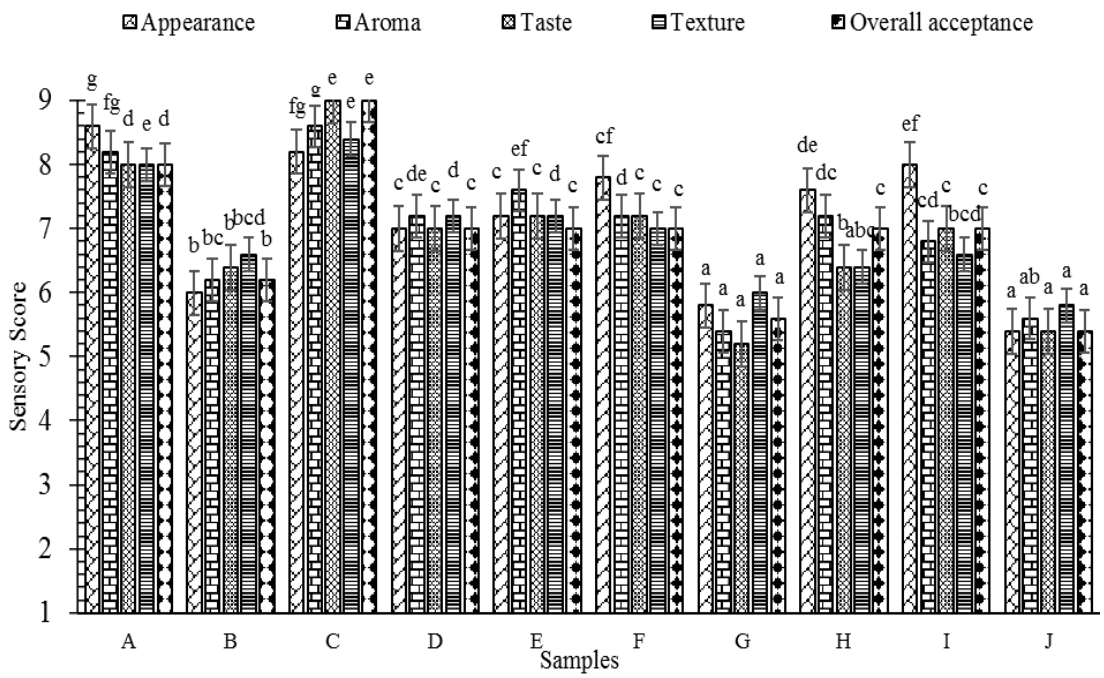

Fig. 3 Mean sensory score for different attributes of the product samples

The similar alphabet above the bar graph indicates no significant difference, and error bars show standard deviation of scores given by 20 panelists.

Overall acceptability
The mean sensory scores for overall acceptability are 8.00, 6.20, 9.00, 7.00, 7.00, 7.00, 5.60, 7.00, 7.00, and 5.40, respectively, for samples A, B, C, D, E, F, G, H, I, and J. The obtained mean values are represented as a bar diagram in Figure 3. The mean sensory score for overall acceptability in sample C is the highest, while the lowest is in sample J. It is due to the uniqueness of noodles and also to the different taste, texture, color, and aroma. Akonor, Tortoe [5] found that, compared to noodles made from the other crops, noodles made from cassava flour showed a higher acceptability rating, which was quite promising.

C. Selection of the best product
Sample C prepared with 23.125:65.625:11.25 cassava flour: wheat flour: gluten ratio was considered to be best in terms of sensory attributes.

Analysis of prepared noodles
The organoleptic analysis of the best product sample is shown in Table 3.

TABLE III. ORGANOLEPTIC ANALYSIS OF BEST PRODUCT SAMPLE (SAMPLE C)

S. N	Parameters	Result
1	Color	Creamish white
2	Smell	Acceptable
3	Texture	Brittle

The proximate composition of noodles prepared from wheat flour and cassava flour, incorporating wheat flour, is presented in Table 4. The crude fiber of cassava-incorporated noodles was found to be 1.80%, while that of wheat noodles was 0.40%. It may be due to the complete removal of the central fibrous portion of the root. The total ash content of cassava flour-incorporated noodles was high. It may be due to the high mineral content of cassava. The protein content of cassava flour-incorporated noodles is high due to the addition of gluten externally. From Table 4, it is clear that the noodles prepared by substituting wheat flour with cassava flour and adding gluten externally increased the crude fiber content and protein content significantly from 0.40% to 1.80% and 12.47% to 18.70%, respectively. Due to an increase in these two parameters, the noodles become more fibrous and more proteinous, which is mostly demanded in today's world.
The moisture, protein, fat, crude fiber, ash, and carbohydrate content of cassava flour-incorporated noodles were found to be 9.37%, 18.70%, 1.20%, 1.80%, 1.26%, and 77.04%, respectively. The obtained results were also comparable to

those of Akonor, Tortoe [5], which reported moisture (5.88–6.17%), protein (11.11–11.98%), ash content (1.88–2.05%), fat (5.40–7.78%), and carbohydrate (72.78–75.28%) in three proportions of cassava flour (50%, 60%, and 70%) noodle. Similarly, Obadina, Oyewole [18] reported 16.20% moisture, 3.90% protein, 1.50% ash content, 0.35% fat, 1.50% crude fiber, and 76.55% carbohydrate in the cassava noodles.

TABLE IV. PROXIMATE COMPOSITION OF WHEAT NOODLES AND CASSAVA FLOUR INCORPORATED NOODLES

Parameters (% Dry basis)	Wheat flour noodle	Cassava flour incorporated noodle (sample C)
Moisture	9.54±0.75	9.37±0.31
Protein	12.47±0.37	18.70±0.14
Crude fat	0.79±0.06	1.20±0.04
Crude fiber	0.40±0.04	1.80±0.03
Total ash	0.89±0.02	1.26±0.01
Carbohydrate	85.43±1.03	77.04±0.29

Values are the means of a triplicate analysis. Figures after ± indicate the standard deviation.

D. Cooking test of the product

Cooking time

The cooking time of the best-selected product (sample C) was found to be 6±0.3 minutes. The findings are lower compared to Omeire, Nwosu [43], who reported that the cooking time of cassava noodles (80 parts wheat flour, 10 parts cassava flour, and 10 parts defatted flour) ranged from 10 to 16 minutes. The cooking time of the noodles differs due to their compositional differences. The cooking time of the selected product is shorter than that of wheat noodles, whose cooking time is 7±0.3 minutes; the difference may be attributed to the use of composite flour in their production [43, 44]. According to Pokharel [26], the cooking time of the noodles prepared from composite flour was found to be 8±0.00 minutes. The cooking time of the selected product was found to be less than that of the wheat-buckwheat-malt composite flour.

Cooking loss

Short cooking times and minimal solid loss in the cooking water are characteristics of high-quality noodles [45]. Omeire, Nwosu [43] found that the solid loss on composite flour containing defatted flour and 10 parts cassava was between 3.44 and 22.32 grams. The cooking loss of the selected product was calculated and found to be 3.8±0.91%, while that of wheat noodles was 5.1±0.3%. The cooking loss of the selected product is less than that of the wheat flour noodles. This is due to the addition of gluten to composite flour. The external addition of gluten increased the gluten content in the noodles. The binding force between the starch and gluten networks is high due to the addition of gluten externally. Subsequently, the dissolution of starch in the cooking process is low. Due to this, the loss of solids in gruel is low. Also, the addition of gluten increases the strength of the solid content of the noodles to attach within them [43, 45].

E. Water absorption capacity (WAC) of cassava flour incorporated noodles

The water absorption capacity of cassava flour-incorporated noodles was determined, and it was compared with that of wheat flour noodles. The result obtained is shown in Table 5.

TABLE V. WATER ABSORPTION CAPACITY OF CASSAVA FLOUR INCORPORATED NOODLES

Weight (grams)	Cooking time (minutes)	Final weight of wheat noodles (grams)	Final weight of cassava noodles (grams)	W.A.C of wheat noodles (in %)	W.A.C of cassava noodles (in %)
10	2	23.06±0.05	23.95±0.60	120.57±0.51	139.50±6.00
10	4	23.14±0.03	29.51±0.08	131.43±0.32	195.10±0.80
10	5	23.18±0.02	29.73±0.24	131.80±0.20	197.30±2.40
10	6	23.62±0.02	30.02±0.23	136.17±0.21	200.20±2.30
10	7	22.17±0.03	31.81±0.20	121.73±0.25	218.10±2.00
10	8	22.13±0.04	31.33±0.42	121.30±0.40	213.30±4.20

Values are the means of a triplicate analysis. Figures after ± indicate the standard deviation.

In Table 5, the initial and final weights of the wheat flour noodles and cassava flour-incorporated noodles were shown at different cooking times. Initially, there was no drastic difference in water absorption capacity between wheat flour and cassava flour-incorporated noodles. When the cooking time gradually increases, the weight of cassava flour-incorporated noodles suddenly increases and reaches 29.51 grams from 10 grams. The increment in weight continues until the cooking time is 7 minutes and the maximum weight is 31.81 grams. After that, there is a slight decrease in the weight of cassava flour-incorporated noodles. Meanwhile, the weight of wheat flour noodles has at least the same increment in weight at different cooking times. Aidoo, Oduro [46] found that the water absorption capacity of two cassava varieties of flour, viz., *Bankye Hemaa* and *Sika Bankye*, was 263%. The above results show that the cassava-incorporated noodles have a higher water-holding capacity than the wheat-flour noodles. The water absorption capacity gradually increases from 139 to 218% as the cooking time increases from 2 to 7 minutes. The maximum water absorption capacity was found to be 218% in 7 minutes of cooking. The high water absorption capacity of cassava-incorporated noodles was due to the hydrophilic constituents of cassava flour, such as polysaccharides. The starch of cassava has higher amounts of amorphous constituents and has more binding sites to absorb more water. The starch in cassava flour requires a certain amount of time to get hydrated and absorb water. So, as the boiling time increases, the water absorption of cassava flour noodles also increases [46, 47].

F. Comparative study of the selected product

The moisture of the selected product (sample C) was found to lie within the limit given [26, 48]. The comparative study of the selected product with the government standard of Nepal is shown in Table 6.

TABLE 6. COMPARISON OF THE SELECTED PRODUCT (SAMPLE C)

S.N.	Characteristics	DFTQC requirement	Selected product (Sample C)
1.	Moisture content % by mass (maximum)	12.50	9.37±0.31
2.	Total protein (% dry basis) (minimum)	8.00	18.70±0.14
3.	Total ash (% dry basis) (maximum)	1.00	1.26±0.01

Values are the means of a triplicate analysis. Figures after ± indicate the standard deviation.
Source : [48]

It indicates that the drying of noodles was satisfactory, and there is no problem with shelf life from the point of view of moisture content if packaging is proper to avoid moisture migration because moisture content affects the quality of the product. The crude protein content of the accepted product was found to be 18.70%, which is satisfactory in comparison to the value set by the Department of Food Technology and Quality Control [48] [26, 48]. According to DFTQC [48], the total ash content of noodle should be below 1%, but the obtained value was 1.26%, which is slightly higher than the value expected by DFTQC. Incorporation of cassava flour may have contributed to the ash content result.

V. CONCLUSIONS

Cassava is known as a staple food source and a crucial crop for food security in developing nations due to its resilience in harsh environmental circumstances [49]. The addition of cassava flour to noodles increased crude fiber as well as water absorption capacity and decreased solid loss. The cooking time of the selected product was found to be shorter than that of wheat flour noodles. Cassava-incorporated noodles contain 18.70% protein, which is higher than wheat flour noodles. Cassava noodles were comparatively higher in nutrient content. Noodles produced by applying a 23.125:65.625:11.25 cassava flour:wheat flour:gluten ratio showed good sensory quality compared to wheat flour noodles. This result showed that flour prepared from underutilized cassava can be used in the preparation of noodles with acceptable nutritional and sensory properties, decreasing the use of wheat flour.

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