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EFFECTS OF EXTRUSION COOKING OVER ROASTING ON RETENTION OF NUTRITIONAL QUALITY OF COMPOSITE FLOUR PREPARED FROM SOYABEAN, MILLET, CORN AND RICE BLEND

– Research paper –

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Abstract: The objective of this study was to compare the effects of extrusion cooking and roasting on the nutritional composition of the blend obtained from rice, soybean, millet and corn flours. Two different flour compositions with different proportions of ingredients were prepared. Roasting process was conducted at 160°C for a duration of 30 minutes, whereas extrusion cooking was performed at 129°C for approximately 5 minutes. Chemical analysis was carried out on all four samples. The findings revealed that the moisture and carbohydrate content in the extrusion-cooked samples (A and B) were higher than in the roasted samples (A' and B'). In contrast, crude fat content, crude fiber content, and ash contents were higher in roasted samples (A' and B') compared to extrusion-cooked samples (A and B). The protein content of samples A, A', B and B' was found to be 10.67%, 8.47%, 14.64% and 9.18%, respectively. This proven protein content is higher in extruded composite flours (A and B). Additionally, calcium and iron contents were higher in the roasted samples, with sample B' having the highest calcium and iron contents. Tannin content and phytic acid content was also higher in the roasted samples, with sample B' having the highest tannin and phytic acid content. In conclusion, extrusion cooking increased nutritional content while reducing anti-nutritional components in the composite flour, suggesting its potential as a preferred processing method to maintain nutritional quality.

Keywords: Anti-nutrient, Composite flour, Extrusion, Roasting

INTRODUCTION

Composite flour is a mixture of flours sourced from starchy tubers like yam, cassava and potatoes as well as protein-rich flours and grains. It may or may not contain wheat flour and is formulated to meet specific functional properties and nutritional values (Noorfarahzilah et al., 2014). For developing nations, there were a few benefits to using composite flours in terms of: i) saving physical cash; ii) encouragement of native plant species with large yields; iii) improved protein availability for human nutrition; and iv) better overall utilization of domestic agricultural production (Bugusu et al., 2001). Composite flour is regarded beneficial in emerging nations since it reduces import of wheat flour and promotes the use of locally cultivated crops (Hasmadi et al., 2014). Therefore, numerous developing countries have endorsed initiatives to evaluate the viability of substituting wheat flour with flour accessible within the community (Abdelghafor et al., 2011). According to FAO, incorporating composite flour into food items could yield economic advantages, especially if there's a reduction or elimination of wheat imports. Meeting the demand for bread and baked goods could be achieved by utilizing locally cultivated ingredients rather than relying on wheat (Jisha et al., 2008).
Baked products prepared from composite flour exhibited commendable quality and shared certain characteristics comparable to those found in wheat flour bread. Despite having a distinct texture and set of characteristics from bakery goods made from wheat flour, composite flour products had a better appearance and nutritious content. Wheat is considered nutritionally deficient because of its cereal proteins, despite being a good source of calories and various nutrients, lack essential amino acids like threonine and lysine (Dhingra & Jood, 2002). Nepal's diverse agroecological, climatic, and soil conditions (Parajuli et al., 2022) are well-suited for cultivating a broad spectrum of agricultural

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crops which is appropriate for growing a wide range of agricultural produces. Millet is the fourth most produced cereals in Nepal (Dangal et al., 2021a). For the purpose of enhancing people's nutritional status and maximizing the use of underutilized crops like millet, products can be created and produced as functional foods (Dangal et al., 2021b). It is possible to successfully incorporate different types of flour into wheat flour bakery items in various ratios to produce baked items with improved nutritional qualities and acceptable sensory characteristics. Therefore, the development and use of bakery products will not only help those with degenerative diseases, but also improve the nutritional status of the population as a whole (Dalal & Bobade, 2018). The food products prepared with higher nutritional value adds flavor and value to our traditional foods while also potentially helping in the fight against protein-energy deficiency (Dahal et al., 2022a). Maintaining and enhancing the nutritional value of foods while they are being processed are the main considerations for the market and industry. Some sustainable and appropriate processing methods are also available that mainly improves or leaving the nutritional content of foods unaffected. Extrusion cooking and other thermal processing methods are frequently used in the production of food items (Moreno et al., 2018). Many beneficial effects or biochemical changes are brought about by extrusion cooking, including starch gelatinization, denaturation of protein, decreased lipid oxidation, formation of volatile flavor components, inactivation of microbes and enzymes, and an increase in soluble dietary fiber. Extrusion cooking additionally has the potential to enhance the nutritional value of the products by increasing the retention of bioactive compounds with antioxidant properties, and improving the starch and protein digestibility (Tiwari, 2018). It might be beneficial to move toward scientific development in order to enhance and diversify the traditional product (Chhetri et al., 2022). This research aims to evaluate and compare the effects of two distinct food processing methods, extrusion cooking and roasting, on the nutritional quality retention in composite flour prepared from a blend of soybeans, millet, maize and rice. The study's goal is to provide valuable insights into which processing technique is most effective in preserving nutritional content of composite flour, which can have significant implications for food production and nutrition initiatives, particularly in areas where such composite flours are commonly used as dietary staples. This work covers an important part of food processing and quality control, adding to our understanding of how to enhance the nutritional content of blended flours to promote nutrition outcomes.

MATERIALS AND METHODS

Collection of raw materials

Rice *(Oryza satia),* Millet *(Eleusine coracana)*, Soybean *(Glycine max)* and Maize/corn *(Zea mays)* were collected from the market of Itahari (26.6646° N, 87.2718° E)**.**

Preparation of composite flour

All the collected grains were pre-dried using sun drying methods and winnowed to remove lighter particles. Two samples were prepared by mixing all four ingredients keeping corn grits and soyabean constant ratio of 60% and 15% respectively and mixing the rice and millet as shown in Table1.

Table 1: Mixing ratio of rice, soybean, millet and maize to prepare composite flour

Ingredient	Sample A	Sample B
Corn grits	60%	60%
Rice	20%	15%
Millet	5%	10%
Soya	15%	15%

The samples were grinded in hammer mill with 2 mm sieve to obtain grits upto 2 mm size. Two samples A and B were extruded through screw type extruder at 129±5°C about 5 min at 100 kg/hr feed rate. Also, the samples A and B were roasted in an electric oven for 30 minutes at 160°C. After roasting, grains were allowed to cool to room temperature. The roasted samples of composition A and B were denoted by A' and B' respectively.

Proximate analysis

All the chemical analyses were carried out in triplicate. Moisture content, total ash content, crude fat content, crude protein content, and crude fiber content of samples were calculated using the methodology outlined by AOAC (1990). Carbohydrate content was determined by difference method (Dahal et al., 2022b) (Eq. 1):

Total Carbohydrate (%) = 100 – (fat % + protein % + ash % + moisture %+ crude fiber %) (1)

Calcium content analysis

The calcium content was assessed using the

potassium permanganate method, following the procedure outlined in Rai & KC (2007) (Eq. 2 & 3):

$$Titer=\frac{4(V1+V2+V3)}{3}+V4 \quad (2)$$

where, $V1$, $V2$, and $V3$ = titer of the flasks 1, 2 and 3, respectively; $V4$ = volume of $KMnO4$ consumed by filter paper

$$Ca^{++}\ (mg/100g,\ dry\ basis) = \frac{Titer\times 0.2\times Vt\ (ml)\times 100*\times 100}{Ve\ (ml)\times Wt.of\ sample\ (g)\times Dry\ matter\ (\%)} \quad (3)$$

Where V_t=total volume of ash solution; V_e=volume taken for estimation;

* =volume made up (in the above case, 100ml)

Iron content analysis

The iron content of sample was determined by transforming all the iron into its ferric form using oxidizing agents such as hydrogen peroxide (H_2O_2) or potassium persulfate ($K_2S_2O_8$). The resulting solution was treated with potassium thiocyanate (KSCN) to produce the red ferric thiocyanate and measured calorimetrically at a wavelength of 480nm (Rai & KC, 2007) (Eq. 4).

Tannin content determination

In a 10 mL volumetric flask, 0.1 mL of the centrifuged extract was combined with 7.5 mL of distilled water, 0.5 mL of Folin-Ciocalteu reagent, and 1 mL of 35% Na_2CO_3. The total volume was adjusted to 10 mL with distilled water. This mixture was allowed to stand for 30 min, and subsequently, the absorbance of the solution was recorded at 700 nm using a spectrophotometer (Kavitha & Indira, 2016). A standard curve was constructed using tannic acid, and the tannin content in the sample was quantified in terms of milligrams of tannic acid equivalent (TAE) per 100g.

Determination of phytic acid

Extraction of phytic acid was done using trichloroacetic acid. This extract was precipitated as ferric salt, and the iron content in the precipitate was determined using a spectrophotometer. A constant molecular ratio of 4Fe:6P was assumed in the precipitate (Wheeler & Ferrel, 1971).

Statistical analysis

The analysis was carried out in triplicate. Using the statistical software SPSS Version 20, all of the collected data were examined for significance using Analysis of Variance (ANOVA). Fisher's protected LSD (Least Significance Difference) was used to compare means at the 5% level of significance.

$$Iron(mg/100g)=\frac{[(mg\ iron\ per\ ml\ of\ standard\ solution)\times(Absorbance\ of\ sample)\times(Total\ volume\ of\ ash\ solution\ ml)\times(100\times100)]}{(Aliquot\ of\ ash\ solution\ ml)\times(Absorbance\ of\ standard)\times(wt.of\ sample\ taken\ for\ ashing)} \quad (4)$$

RESULT AND DISCUSSIONS

Proximate analysis of grains (Rice, corn, millet and soybean)

The moisture, protein, fat, crude fiber, ash and carbohydrate content of rice were found to be 12.82%, 7.32%, 0.65%, 0.39%, 0.48% and 78.32% respectively (Table 2). The result obtained aligned closely with the findings reported by Chaudhari et al. (2018). Also, ObembeOlusola et al. (2022) reported the moisture content (8.36% - 10.98 %), protein content (5.65% - 8.34%), fat content (0.71% - 0.91%), ash content (0.53%-1.19%), crude fiber (1.23-1.53%) and carbohydrates (77.15%-88.20%) in four different varieties of rice.

The moisture, protein, fat, crude fiber, ash and carbohydrate content of corn were found to be 11.82%, 7.33%, 5.08%, 1.97%, 1.46% and 78.32% respectively (Table 2). According to Qamar et al. (2016), the proximate composition of maize was found to be as moisture content in the range of (8. 98 to 10.45%), ash (0.81 to 1.35%), crude fiber (0.79 to 2.78%) and crude protein (11.05 to 12.79%). The obtained result was similar to that reported by FAO (1992).

The moisture, protein, fat, crude fiber, ash and carbohydrate content of millet were found to be 10.89%, 12.17%, 4.19%, 3.14%, 0.98% and 68.61% respectively. The obtained result was similar to that reported by Amadou et al. (2011). The obtained results were also similar to Malik et al. (2021) which reported as moisture (8.03%), protein (14.38%), ash content (1.84%), crude fiber (1.34%) fat (5.40%) and carbohydrate (68.99%).

The moisture, protein, fat, crude fiber, ash and carbohydrate content of soybean were found to be 9.11%, 38.86%, 18.31%, 6.43%, 4.13% and 23.13%. The result was similar to that reported by Banaszkiewicz (2011). Similarly, Etiosa et al. (2018) reported 37.69% of protein, 28.20% of crude fat, 4.29% of ash, 8.07% of moisture, 5.44% of fiber and 16.31% of carbohydrate in the soyabean. The protein content obtained was comparable to the findings published by Pokharel et al. (2023).

Proximate analysis flour blend obtained from different treatment

The proximate analysis of all the four samples were done and the results obtained are presented in Table 3.

Table 2: Proximate composition of rice, corn, millet and soybean

Parameters	Rice	Corn	Millet	Soybean
Moisture (%)	12.82 (0.38)	11.82 (0.27)	10.89 (0.22)	9.11 (0.41)
Crude protein (%)	7.32 (0.48)	7.33 (0.15)	12.17 (0.33)	38.86 (2.33)
Crude fat (%)	0.65 (0.08)	5.08 (0.19)	4.19 (0.33)	18.31 (0.66)
Crude fiber (%)	0.39 (0.05)	1.97 (0.22)	3.14 (0.40)	6.43 (0.60)
Total ash (%)	0.48 (0.03)	1.46 (0.25)	0.98 (0.12)	4.13 (0.41)
Carbohydrate (%)	78.32 (0.16)	78.32 (0.99)	68.61 (0.48)	23.13 (3.04)

Table 3: Proximate composition of composite flour

Parameters	A	B	A'	B'
Moisture (%)	8.94 (0.85)	7.85 (0.23)	6.49 (0.31)	6.06 (0.07)
Protein (%)	10.67 (0.50)	14.64 (0.48)	8.47 (0.27)	9.18 (0.12)
Fat (%)	6.13 (0.19)	7.89 (0.23)	6.76 (0.14)	9.24 (0.36)
Crude fiber (%)	2.38 (0.21)	2.96 (0.31)	4.42 (0.42)	3.53 (0.31)
Ash (%)	1.64 (0.20)	1.33 (0.07)	2.76 (0.26)	2.29 (0.24)
Carbohydrate (%)	70.21 (0.92)	65.31 (1.09)	71.07 (0.61)	69.68 (0.87)

With increase in rice proportion and decrease in millet proportion in composite flour, moisture content, total ash and carbohydrate content increases while protein, fat and crude fiber decreases. As the moisture and carbohydrate content is higher in rice than in millet, the moisture of the composite flour with higher rice, flour and lower millet flour may have higher moisture and carbohydrate content than other samples. Similar type of result was obtained by Bolarinwa et al. (2015) during the preparation of soy based composite flour.

The moisture content and protein are lesser during roasting than extrusion cooking. Similarly, there was reported significant decrease in protein content in soy flour after roasting (Moreno et al., 2018). While carbohydrate, total ash, fat and crude fiber is higher for roasting than extrusion cooking. During the extrusion process, desulphated bonds split and reassemble, while the high molecular proteins separate into smaller subunits. It was also noted that the nutritional value of the vegetable protein increased as a result of the mild extrusion processing conditions (Sundarrajan, 2014). The mineral composition of the extrudates was higher than that of the individual raw samples, indicating that the extrudates nutritional value had been enhanced by fortification. This increase has been linked to extruder screw wear (Anuonye et al., 2010). There was a notable and statistically significant ($P<0.05$) increase in the fat content of the extruded blend. This indicates that blending had enhanced the proximate composition, as reported by Anuonye et al. (2010). The reduction in protein content could be attributed to the gelatinization effect induced by the extrusion processing.

Effects in calcium content during extrusion cooking and roasting

The calcium content for sample A, B, A' and B' were found to be 136.73 mg/100 g, 279.07 mg/100 g, 159.94 mg/100 g, 281.43 mg/100 g respectively. The difference in calcium content between A and B, A' and B' (Figure 1) may be due to the proportion of grain used as calcium content is high in millet. Phytic acid is accountable for binding calcium, making it unavailable. Roasting leads to an increase in calcium content due to a reduction in phytic acid levels (Tiwari & Awasthi, 2014).

Effects in iron content during extrusion cooking and roasting

The iron content for sample A, B, A' and B' were measured to be 9.08 mg/100 g, 12.57 mg/100 g, 2.49 mg/100 g and 5.16 mg/100 g respectively (Figure 2). In the comparison of the two processing methods, a notably higher reduction of iron occurs during the roasting process. The decline in iron content noted during roasting may be attributed to prolonged exposure to high temperatures, in contrast to the short processing time associated with extrusion cooking, which involves high temperatures but for a shorter processing time (Salif Sow et al., 2019).

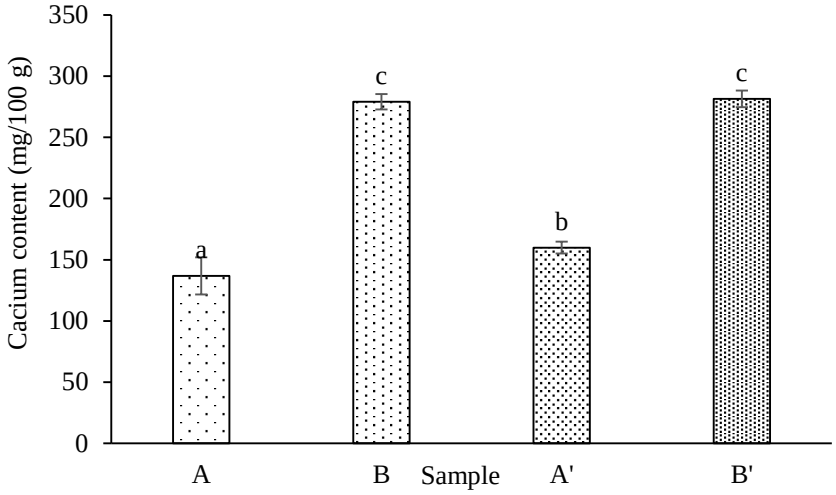


Figure 1. Calcium content of composite flour after extrusion and roasting

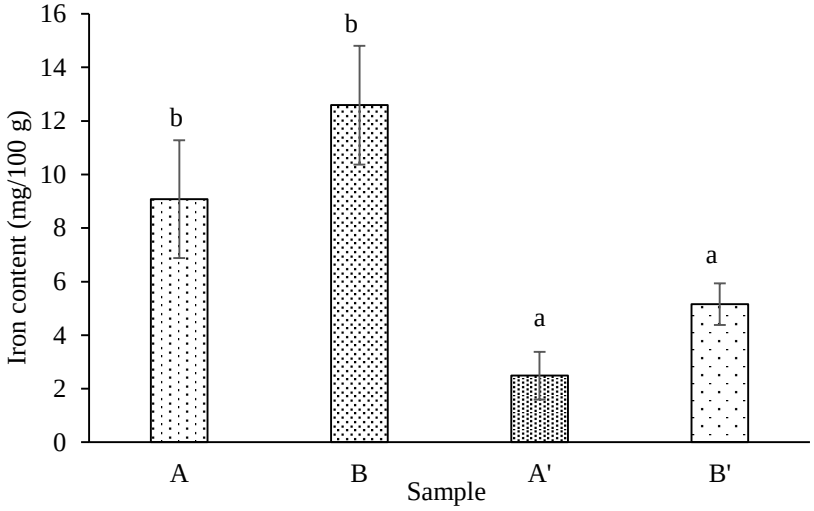


Figure 2. Iron content of composite flour after extrusion and roasting

Effects in tannin content during extrusion cooking and roasting

The tannin content for sample A, B, A' and B' were found to be 9.51 mg/100 g, 11.32 mg/100 g, 15.08 mg/100 g and 17.73 mg/100 g respectively. From the Figure 3, It is evident that extrudates have lower tannin levels. This indicates that extrusion cooking resulted in a noteworthy ($P<0.05$) reduction in this antinutrient compared to roasting.

In extrusion cooking, while the temperature might be lower than that of roasting, the process involves intense mechanical forces, high pressure, and shearing action due to the extrusion machine. These conditions lead to greater exposure of the grain's surface area to the heat, causing more efficient breakdown of tannins. Additionally, the short processing time during extrusion prevents the tannins from re-polymerizing or becoming less accessible to the degradative impact of heat. The reduction may be ascribed to thermal degradation and reduction in the extractability of tannin molecules due to enhanced polymerization or alterations in the chemical reactivity (TV et al., 2018).

Effects in phytic acid content during extrusion cooking and roasting

The phytic acid content for sample A, B, A' and B' were found to be 7.28 mg/100 g, 10.62 mg/100 g, 9.63 mg/100 g and 14.32 mg/100 g respectively (Figure 4).

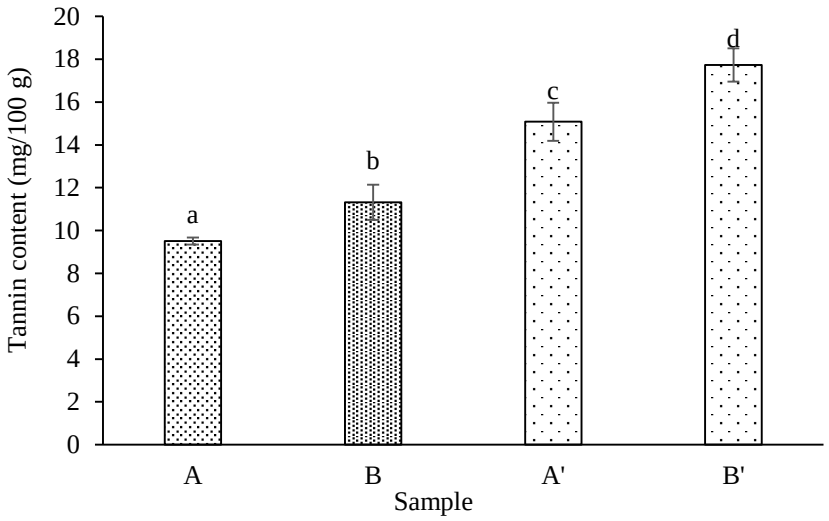


Figure 3. Tannin content of composite flour after extrusion and roasting

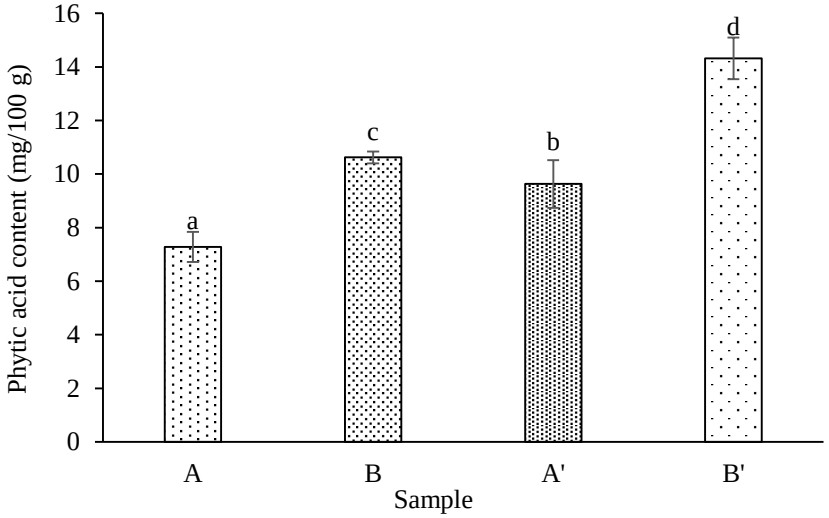


Figure 4. Phytic acid content after extrusion and roasting

From the Figure 4, it can be seen the levels of phytates was reduced in extrudates. This indicates that extrusion cooking led to a notable and statistically significant ($P<0.05$) decrease in this antinutrient compared to roasting. The reduction in phytic acid content observed after the extrusion process may be attributed to the hydrolyzation of inositol into lower molecular weight forms, such as tetra-, penta-, and triphosphates. Another contributing factor could be the breaking apart of phytates and creation of not soluble complexes with other constituents (TV et al., 2018).

CONCLUSION

In the prepared composite flour, with the increase in rice proportion and decrease in millet proportion in composite flour moisture content, total ash and carbohydrate content increases while protein, fat and crude fiber decreases. Moisture and protein were found to be greater in extrusion than in roasted sample. Phytic acid and tannin content decreased during extrusion cooking as compared to roasting. Extrusion cooking can be used as pre-treatment to reduce the anti-nutritional factors (ANFs).

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CONFLICT OF INTERESTS
None

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