Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

AMELIORATIVE EFFECT OF INDUSTRIAL WASTE RICE HUSK ON LEVELS OF B VITAMIN IN EXTRUDED BREAKFAST CEREALS

MADIHA ROHI *
Assistant Professor, Department of Food Science and Technology, Government College Women University, Faisalabad. *Corresponding Author Email: dr.madiharohi@gcwuf.edu.pk

RIZWANA BATOOL
Assistant Professor, Department of Food Science and Technology, Government College Women University, Faisalabad. Email: dr.rizwanabatool@gcwuf.edu.pk

MAHREEN ABDUL SATTAR
PhD Research Associate, Department of Food Science and Technology, Government College Women University, Faisalabad. Email: mahreensattar507@gmail.com

KAYNAT MALIK
Mphil Research Associate, Department of Food Science and Technology, Government College Women University, Faisalabad. Email: 2015-gcwuf-3118@student.gcwuf.edu.pk

SIDRA YASIN
Supporting Staff, Department of Food Science and Technology, Government College Women University, Faisalabad. Email: sidrayasin09@gmail.com

Abstract

Rice (*Oryza Sativa L.*) and corn (*Zea mays L.*), two major agricultural crops, produce significant amounts of byproducts during processing. Rice husk, a byproduct of rice milling, contains essential B vitamins such as thiamine (B_1), riboflavin (B_2), niacin (B_3), and pyridoxine (B_6), which are crucial for metabolic processes and overall health. Similarly, corn grits, derived from ground corn, are key ingredients in extruded foods such as breakfast cereals and snacks. This study focuses on developing extruded breakfast cereals by incorporating rice husk and corn grits to enhance their B vitamin content and nutritional profile. Sensory analysis was conducted to evaluate the acceptability of the developed breakfast cereals. The study aims to optimize the extrusion process to retain the maximum amount of B vitamins while ensuring the sensory qualities meet consumer preferences. It is determined that extruded snacks can retain larger levels of heat-labile B vitamins when cooked at a high temperature for a short period of time and the amount of B vitamins observed was B_1 0.035 mg/100g, B_2 0.028 mg/100g, B_3 0.53 mg/100g, and B_6 0.02 mg/100g. Extrudates were evaluated using a nine-point hedonic scale to determine the acceptability of the product. The extrudate with the best overall acceptability and the optimum physical and chemical properties contained rice husk 40% and corn grit 60%.

Keywords: Rice Husk; Breakfast Cereals, B Vitamins; Extrusion; Sensory Analysis.

1. INTRODUCTION

The cereal grain production and processing industry play a crucial role in global food supply, yet it contributes significantly to food waste. With cereal processing accounting for approximately 12.9% of worldwide food waste, there is a pressing need to explore innovative ways to utilize cereal byproducts effectively. Among the cereals, rice, corn, barley, and wheat are the most consumed, representing over 90% of total cereal consumption (Farcas *et al.,* 2022).

Rice (*Oryza Sativa L*.), being one of the most important crops globally, generates significant byproducts like husk and bran during processing. Rice husk, in particular, is rich in nutrients and bioactive compounds, making it a valuable resource for various applications, including food production. With around 150 million tons of rice husks produced annually worldwide, there is a considerable opportunity to harness this agricultural waste (Uzoamaka *et al.,* 2023). Rice husk boasts an impressive nutritional profile, containing essential minerals, proteins, fiber, and B complex vitamins. Similarly, rice bran, a byproduct of rice milling, is rich in bioactive compounds and nutritional elements. However, traditional processing methods often lead to the loss of vital nutrients like B vitamins, emphasizing the importance of innovative approaches to preserve nutritional value (Tas *et al.,* 2021).

Corn (*Zea mays L.*), another staple crop, contributes significantly to global agriculture, with various parts of the corn kernel being utilized for different purposes. Corn grits, derived from ground corn, serve as a key ingredient in extruded foods, such as breakfast cereals and snacks. As consumer preferences shift towards healthier options, there's a growing demand for nutritious and convenient food products, driving innovation in the breakfast cereal and snack food industries (Khantham *et al.,* 2022).

The extrusion process is a high-temperature short-time processing technology, which includes mixing, forming, texturizing and cooking (Kantrong *et al.,* 2018). Extrusion technology has emerged as a cost-effective and efficient method for producing a wide range of cereal-based products. By combining cereals, starches, and vegetable proteins, extrusion allows for the creation of diverse food items with desirable textures and nutritional profiles (Chauhan *et al*., 2019). A long barrel extruder has a lesser vitamin B retention rate after extrusion processing compared to a short barrel extruder (90mm). In comparison to the oat, pyridoxine in corn was more stable during extrusion heating (Nitu *et al.,* 2023).

The extrusion process is integral to the production of various food products, including breakfast cereals, snacks, noodles, and pasta. By utilizing a combination of cereals-based composite flour and starches, extrusion-based food processing industries can tailor products to meet consumer preferences and nutritional requirements. The incorporation of rice husk and corn grits into composite materials presents an opportunity to enhance the nutritional profile and quality attributes of extruded products, such as breakfast cereals.

2. MATERIALS AND METHODS

The project research activity was carried out at the Food Technology Lab Department of Food Science and Technology, Govt. College Women University, Faisalabad. This research work was carried out to evaluate proximate composition, calorific value and B vitamins of composite flour (rice husk and corn grit) as well as proximate analysis, B vitamins and sensory attributes of extruded breakfast cereals.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

2.1. Procurement of Raw Material

Rice husk was collected from local industries and Five Star Rice Processing Mill located in Faisalabad near Circular Club. The remaining ingredients required for the preparation of the extruded product were purchased from Amar Foods, Faisalabad. All reagents, chemicals and standards required for the analysis were procured from Sigma-Aldrich Lab.

2.2. Preparation of Rice Husk Powder

The rice husk was washed with running water to remove dust contamination and dried in a hot air oven until completely dried. After drying, the rice husk was ground to form powder by screening through the sieves. Powder formation was done at Saad Bella Milling, Faisalabad and then packed in airtight plastic stacks and stored at room temperature before auxiliary use.

Table 1: Treatments Plan for Extruded Breakfast Cereals

Treatments	Bulking Agent (Corn Grit) %	Rice Husk %
T_0	100	0
T_1	90	10
T_2	80	20
T_3	70	30
T_4	60	40
T_5	50	50

Treatment plan has been selected on trial basis

2.3. Preparation of Extruded Breakfast Cereals

An extruder with twin screws was used to prepare the product. Various proportions of rice husk and corn grit were made in accordance with the treatment plan. The extruded breakfast cereals were prepared in an extruder. The extruder simply operates the shaping of a plastic dough-like material that forces the dough through a die or restriction. The die temperature was set at 189.3 °C with 250 RPM. The extruder parameters were selected to get the desired end product with good textural quality (crispiness, hardness, and expansion). The extruded breakfast cereals coming out from the die exit were cut by a rotating knife. These extruded breakfast cereals were collected and cooled at ambient temperature and packed in sealed plastic bags for further analysis (Aryane *et al.,* 2023).

2.4. Analysis of Raw Material (Corn Grit and Rice Husk)

2.4.1. Proximate Analysis of Raw Material

The proximate analysis of raw material (crude fiber, crude protein, crude ash, crude fat, crude moisture and NFE content) was determined by the method described in AACC (2016).

2.4.2. B vitamin analysis of Raw Material

The B vitamin analysis of raw material (thiamine (B_1), riboflavin (B_2), niacin (B_3), and pyridoxine (B_6) was determined by the method described by Aslam *et al.* (2008).

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

2.5. Analysis of composite flour

2.5.1. Proximate Analysis of Composite Flour (Corn Grit and Rice Husk)

Proximate analysis (crude fiber, crude protein, crude ash, crude fat, crude moisture and NFE content) of composite flour was done by the method as described in AACC (2016).

2.5.2. Calorific Value of Composite Flour

The calorific value (Kcal/100g) of composite flour was calculated by summing up the composite flour multiplication of percent protein, fat, and carbohydrate present in composite flour (Saraswathin *et al.,* 2018). The calorific value of composite flour was measured by using the formula:

Calorific Value of Composite Flour = (Crude Protein %) × 4 + (Carbohydrate %) × 4 + (Crude Fat %) × 9

2.6. Analysis of Extruded Breakfast Cereals

2.6.1. Proximate Analysis of Extruded Breakfast Cereals

2.6.1.1. Crude Moisture Content of Extruded Breakfast Cereals

The crude moisture content of extruded breakfast cereals was determined by weighing a 5g sample. The samples were kept at 105 ± 5 °C in a hot air oven for about 24 hours. Following that, the total samples were placed in a desiccator to cool down without absorbing moisture from the environment. The dried samples were weighed again till the constant weight was attained as mentioned in AACC (2016) method 44-15A. The obtained moisture content was calculated by the subsequent given formula:

$$Crude\ Moisture\ Content\ \% = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight} \times 100$$

2.6.1.2. Crude Protein Content of Extruded Breakfast Cereals

The protein content was determined according to the procedure given in AACC (2016) method 4-15A. Accurately weighed 0.2-0.5g finely ground sample was placed in the digestion tube. 5g of the digestion mixture and 30 mL of concentrated H_2SO_4 was added in a sample tube. Digestion tube was placed on the digestion block. Then it was covered with an exhaust system and turned on. Switched on the digestion assembly and heated for 3-4 hrs, till 1-2mL of transparent or light grey solution remains in the flask. Flask was allowed to cool but avoid crystallization. The volume of the sample was made up to 100-250mL with distilled water. 10mL of diluted sample and 40% NaOH solution was taken for further distillation. 4% boric acid was added in a conical flask along with a methyl red indicator and the ammonia liberated from distilled water was collected. Then titrated with standard NaOH solution. The percent protein content was calculated by the following formula:

$$Nitrogen\ \% = \frac{Volume\ of\ 0.1\ NH_2SO_4 \times Volume\ of\ dilution\ made \times 0.0014}{Weight\ of\ Sample\ (g) \times Volume\ of\ dilution\ taken\ (mL)} \times 100$$

Crude Protein % = %N × 6.25

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

2.6.1.3. Crude Fat of Extruded Breakfast Cereals

The crude fat content of extruded breakfast cereals was determined by the use of Hexane as a solvent in a soxhlet apparatus with continuous reflux as defined in AACC (2016) method 30-25. First of all, the 5g sample of each treatment was wrapped with already-weighed filter paper. All the wrapped samples were placed in a soxhlet column that is attached to a weighted oil extraction flask comprising almost 300mL of Hexane (40 to 60°C boiling point). The wrapped samples were defatted three times and the fat content was calculated by weight difference for individual samples and expressed as a percentage of the sample weight. The percentage of crude fat content was calculated by using the following formula:

$$Fat\ \% = \frac{Weight\ of\ sample\ before\ extraction - Weight\ of\ sample\ after\ extraction}{Weight\ of\ sample\ before\ extraction} \times 100$$

2.6.1.4. Crude Fiber Content of Extruded Breakfast Cereals

The crude fiber content of extruded breakfast cereals was estimated by taking a fat-free sample as termed in AACC (2016) method 985.29. First of all 5g of defatted sample of each treatment was boiled in 200mL of 1.25% H_2SO_4 solution under the reflux of 30 minutes. After this, the sample was washed with boiling water by using a dual muslin cloth to catch the particles. The washed sample was again boiled for 30 minutes with 1.25% NaOH solution and then cleaned with warm water utilizing a muslin cloth. The resultant filtrate was carefully conveyed into a weighted crucible of porcelain and dried for an hour in a hot air oven. After drying in a hot air oven at ±105°C, then the sample was placed to cool in the desiccator. The dried and cooled filtrate was burnt at 600°C and reweighed (W_2) after cooling of that sample. The loss in weight after drying was calculated as the crude fiber content and expressed as a percentage under the given formula:

$$Crude\ Fiber\% = \frac{Weight\ of\ residue - Weight\ of\ ash\ after\ ignition}{Weight\ of\ sample} x\ 100$$

2.6.1.5. Crude Ash Content of Extruded Breakfast Cereals

The crude ash content of extruded breakfast cereals was estimated through the following procedure as given in AACC (2016) method 923.03. To acquire a consistent weight, the silica dishes were first dried, and then, in a silica dish, a precisely weighed sample (5g) was obtained. The silica dish was placed in a muffle furnace and fired for 2 hours at 550-650°C until white ash was formed. The crude ash-containing silica dish was weighed after cooling in a desiccator. The crude ash content of extruded breakfast cereals was calculated by using the formula:

$$Crude\ Ash\ \% = \frac{Weight\ of\ sample\ before\ ashing - Weight\ of\ sample\ after\ ashing}{Weight\ of\ sample\ before\ ashing} x\ 100$$

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

2.6.1.6. Nitrogen-Free Extract of Extruded Breakfast Cereals

By using the following formula, the NFE content (nitrogen-free extract) was determined by

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

2.6.2. Determination of B Vitamins of Extruded Breakfast Cereals

Estimation of B vitamins thiamine (B_1), riboflavin (B_2), niacin (B_3) and pyridoxine (B_6) of extruded breakfast cereals were analyzed by the method as described by Aslam *et al.* (2008).

2.6.2.1. Standard preparation

In order to prepare the vitamin B_1 (thiamine HCl) standard stock solution, thiamine hydrochloride (26.7mg) was dissolved in double-distilled water (25 ml). Since the extraction solution can only dissolve up to 7 milligram of riboflavin, a standard stock solution containing 6.9 mg of riboflavin was created by dissolving the vitamin in 100 milliliters of extraction solution. Vitamin B_3 (niacin) standard stock solution was created by dissolving nicotinamide (41.5 mg) in double-distilled water (25 ml). Vitamin B_6 (pyridoxine HCl) standard stock solution was made by mixing pyridoxine hydrochloride (20.8mg) with double-distilled water (25 mL).

2.6.2.2. Preparation of Buffer, Solution and Sample

Buffer is prepared by adding sodium salt hexane sulphonic acid (1.08g) and potassium dihydrogen phosphate (1.36g) to 940 milliliters of HPLC water. After that, 5 milliliters of triethylamine were added, and orthophosphoric acid was used to bring the pH down to 3.0. The mobile phase was made up of a 96:4 ratio of methanol to buffer. After that, helium gas was used to degas the mixture after it had passed through a membrane filter. To prepare an extraction solution 10 milliliters of glacial acetic acid was combined with 50 milliliters of acetonitrile. Double-distilled water was then added to get the volume up to 1000 mL. After being homogenized and weighed out at 10 g, each sample was placed in conical flasks containing extraction solution (25ml). Following that, the flasks were placed in a water bath with shaking at 70°C for approximately 40 minutes. The sample was then allowed to cool and filter it before adding an extraction solution to bring the volume up to 50 mL.

2.6.2.3. Estimation of B-Vitamins

After creating the calibration curve with mixed standards in the mobile phase and five-point calibrations, a standard curve between peak area and concentration was generated, which were then separately examined by HPLC. There was good linearity in the injected quantities. The linear least-square regression method was employed to analyze the peak area vs. standard data. The resulting regression equation, which was derived from the standard curve, was then utilized to calculate the amount of water-soluble vitamins in various samples. Using a water pump (1515 isocratic), a water symmetry C18 column

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

(4.6 x 250 mm, 5µm) was used for the HPLC analysis. A UV (2487) detector was used for peak detection, employing two channels simultaneously at 210 nm, a bandwidth of 5 nm, and another wavelength of 280 nm. The linear gradient of methanol: buffer (4:96) was used at a flow rate of about 1 millilitre per minute with 2300 pressure. Three duplicates were used for each analysis. Through recovery study, the accuracy of the current approach was verified in the sample. Extra 50, 100, and 150 percent of the standard vitamins were added to pre-analyzed samples, and the mixes were then reanalyzed using the suggested methodology. Following three repetitions of the experiment, the recovery % was calculated by utilizing a regression equation to estimate the average of the recovered vitamin content. The accuracy of the employed technique was ascertained, and the percent standard deviation (RSD) was calculated, by evaluating the intra- and inter-day variation in the three replicates of vitamins of B-group at two different concentrations (200 to approximately 400 ng per spot). Three identical samples of in vitro and ex-vitro seedlings, each containing 60 µl, were utilized. Using the regression equation of each standard's calibration curve, the vitamin yield was calculated.

2.6.3. Sensory Evaluation of Extruded Breakfast Cereals

Sensory evaluation of extruded breakfast cereals was evaluated for quality characteristics; appearance, crispness, texture, color, aroma, flavor and overall acceptability. Each sensory attribute was rated on 9-point Hedonic Scale (1 = disliked extremely while 9 = liked extremely) according to Ashwar *et al.* (2021).

3. RESULTS AND DISCUSSION

3.1. Nutritional composition of raw material (Corn Grit and Rice Husk)

3.1.1. Proximate composition of raw material (Corn Grit and Rice Husk)

Table 2 indicates the chemical composition of raw material. The average values of proximate composition of corn grit contained crude fat 1.20%, crude fiber 0.97%, crude moisture 11.20%, crude protein 7.53%, crude ash 0.93% and nitrogen-free extract 78.35%. The study conducted by Antun *et al.* (2017) determined the crude moisture, crude fiber, and crude fat content of corn grit that were found 13.61%, 1.18%, and 1.04% respectively. Jozinovic *et al.* (2017) prepared extruded corn snack products and the results showed that the proximate composition of corn grits was, moisture content 13.61%, crude ash content 0.35%, crude fat content 1.04% crude protein content 7.44% and crude fiber content 1.18% respectively. The proximate composition of rice husk was moisture, crude fat, crude protein, crude ash, crude fibre, and NFE content was found 6.72%, 3.70%, 1.82%, 19.11%, 25.60%, and 43.05%, respectively. Uzoamaka *et al.* (2023) determined the proximate composition of rice husk and the results of crude moisture, crude fiber, crude ash, crude fat, and crude proteins were 7.93%, 25.74%, 23.39%, 3.76%, and 1.85% respectively. Elkatry *et al.* (2023) prepared pan bread fortified with rice husk and the proximate composition of rice husk showed a moisture content of 13.38%, crude ash content of 19.90%, and crude fiber content of 78.30%.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

Table 2: Proximate composition of raw material (Corn Grit and Rice Husk)

Raw Material	Proximate Composition (%)					
	Crude Moisture	Crude Fat	Crude Protein	Crude Ash	Crude Fiber	NFE
Corn Grit	11.20	1.02	7.53	0.93	0.97	78.35
Rice Husk	6.72	3.70	1.82	19.11	25.60	43.05

3.1.2. B vitamins contents of raw material (Corn grit and Rice husk)

Table 3 showed the mean vitamin composition of raw materials. The vitamin composition of corn grit was vitamin B_1 0.10mg/100g, B_2 0.05mg/100g, B_3 0.64 mg/100g and B_6 0.06 mg/100g. These findings closely align with the findings directed by Athar *et al.* (2006), where the vitamin content of corn grit was reported as B_1 0.09 mg, B_2 0.04mg, B_3 0.63 mg and B_6 0.04 mg/ per 100g. The vitamin composition of rice husk was found as vitamin B_1 0.29mg/100g, B_2 0.14mg/100g, B_3 0.07 mg/100g and B_6 0.5 mg/100g. These findings closely align with the findings directed by Nnadiukwu *et al.* (2023), where the vitamin content of rice husk was reported as B_1 0.28 mg, B_2 0.12 mg, B_3 0.05 mg and B_6 0.49 mg/ per 100g.

Table 3: Vitamin Contents of Raw Material (Corn Grit and Rice Husk)

Raw Material	Vitamins (mg/100g)			
	B_1	B_2	B_3	B_6
Corn Grit	0.10	0.05	0.64	0.05
Rice Husk	0.29	0.14	0.07	0.5

3.2. Analysis of Composite Flour (Corn Grit and Rice Husk)

3.2.1. Proximate composition of composite flour (Corn Grit and Rice Husk)

3.2.1.1. Crude moisture content of composite flour (Corn Grit and Rice Husk)

Table 4 has indicated the average values of crude moisture content of composite flour. The findings of the composite flour's analysis of variance for crude moisture were very significant ($p \leq 0.01$). The composite flour's mean crude moisture values ranged from 8.95 to 11.23±0.03%. T_0 consisting of 100% corn grit, exhibited the highest crude moisture content of 11.23±0.03%. In contrast, T_5, containing an equal mix of corn grit and rice husk, showed the lowest crude moisture content of 8.95±0.03%. Paterne *et al.* (2019) determined the moisture content in traditional roasted corn flour and the amount of moisture was 13.12%.

3.2.1.2. Crude fat content of composite flour (Corn Grit and Rice Husk)

Table 4 has indicated the average values of composite flour for crude fat content. The findings of the composite flour's analysis of variance for crude fat were very significant ($p \leq 0.01$). The composite flour's mean crude fat values ranged from 1.05 to 3.39±0.03%. T_0 composed of 100% corn grit, displayed the lowest crude fat content of 1.05±0.03%, while T_5, containing an equal percentage of corn grit and rice husk, demonstrated the highest crude fat content of 3.39±0.03%. Amer and Rizk (2022) determined the fat content in corn grits and it was found to be 3.55%.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

3.2.1.3. Crude protein content of composite flour (Corn Grit and Rice Husk)

Table 4 has indicated the average values of composite flour for crude protein content. The findings of the composite flour's analysis of variance for crude protein were very significant ($p \leq 0.01$). The composite flour's mean crude protein values ranged from 4.33 to 7.56±0.03. T_0, composed of 100% corn grit, and exhibited the highest crude protein content at 7.56±0.03%. In contrast, T_5 consisting of an equal mix of corn grit and rice husk, showed the lowest crude protein content at 4.33±0.03%. Similar findings were done by Amer and Rizk (2022), they determined crude protein content in corn grits and it was found 8.88%.

3.2.1.4. Crude ash content of composite flour (Corn Grit and Rice Husk)

Table 4 has displayed the average values of composite flour for crude ash content. The findings of the composite flour's analysis of variance for crude ash were very significant ($p \leq 0.01$). The composite flour's mean crude ash values ranged from 1.00 to 13.31±0.03 %. The data showed a consistent increase in crude ash content as the proportion of rice husk increased in the composite flour. T_0, consisting of 100% corn grit, exhibited the lowest crude ash content of 1.00±0.03%, while T_5, containing an equal proportion of corn grit and rice husk, demonstrated the highest crude ash content that was 13.31±0.03%. This trend suggests that the inclusion of rice husk has a substantial impact on elevating the crude ash content of the composite flour. Amer and Rizk (2022) determined crude ash content in corn grits and it was found to be 0.65%.

3.2.1.5. Crude fiber content of composite flour (Corn Grit and Rice Husk)

Table 4 has exposed the average values of composite flour for crude fiber content. The findings of the composite flour's analysis of variance for crude fiber was very significant ($p \leq 0.01$) The composite flour's mean crude fiber values ranged from 0.96 to 10.03±0.03%. The data demonstrates a consistent increase in crude fiber content as the proportion of rice husk in the composite flour increases. T_0, consisting of 100% corn grit, exhibited the lowest crude fiber content that was 0.96±0.03%, while T_5, with an equal proportion of corn grit and rice husk, displayed the highest crude fiber content that was 10.03±0.03%. Amer and Rizk (2022) determined crude fiber content in corn grits and it was found to be 2.24%.

3.2.1.6. Nitrogen-free extract (NFE) content of composite flour (Corn Grit and Rice Husk)

Table 4 has exposed the average values of composite flour for NFE. The findings of the composite flour's analysis of variance for NFE content were very significant ($p \leq 0.01$). The composite flour's mean NFE values ranged from 59.99±0.03 to 78.2±0.03%. T_0, composed of 100% corn grit, exhibited the highest NFE content (78.2±0.03%), while T_5, with an equal mix of corn grit and rice husk, displayed the lowest NFE content (59.99±0.03%). The impact of maize grits' moisture content and particle size on the enlarged snack's physical characteristics was noted by Sohrab *et al.* (2020). The range of the NFE content was 74.81% to 76.49%.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

Table 4: Mean values for proximate composition of composite flours (Corn Grit and Rice Husk)

Treatments	Proximate compositions (%)					
	Crude Moisture content	Crude Fat	Crude Protein	Crude Ash	Crude Fiber	NFE
T_0	11.23±0.03^A	1.05±0.03^F	7.56±0.03^A	1.00±0.03^F	0.96±0.03^F	78.2±0.03^A
T_1	10.78±0.03^B	1.31±0.03^E	6.83±0.03^B	3.46±0.03^E	2.77±0.03^E	74.85±0.03^B
T_2	10.33±0.03^C	1.58±0.03^D	6.32±0.03^C	5.92±0.03^D	4.59±0.03^D	71.26±0.03^C
T_3	9.52±0.03^D	1.85±0.03^C	5.70±0.03^D	8.38±0.03^C	6.41±0.03^C	68.14±0.03^D
T_4	9.43±0.03^E	2.12±0.03^B	5.08±0.03^E	10.85±0.03^B	8.04±0.03^B	64.48±0.03^E
T_5	8.95±0.03^F	3.39±0.03^A	4.33±0.03^F	13.31±0.03^A	10.03±0.03^A	59.99±0.03^F

T_0= 100% Corn Grit
T_1= 90% Corn Grit + 10% Rice Husk
T_2= 80% Corn Grit + 20 % Rice Husk
T_3= 70% Corn Grit + 30 % Rice Husk
T_4= 60% Corn Grit + 40 % Rice Husk
T_5= 50% Corn Grit + 50% Rice Husk

3.2.2. Calorific Values of composite flour (Corn Grit and Rice Husk)

Table 5 displayed the average values of composite flour for calorific value. The findings of the composite flour's analysis of variance for calorific value were very significant ($p \leq 0.01$). The average calorific value of composite flour (corn grit and rice husk) ran4ged from 276.67 to 350.41±0.03kcal. Treatment T_0, comprising 100% corn grit, demonstrates the highest calorific value at 350.41±0.03kcal. Treatment T_5, with an equal proportion of corn grit and rice husk, exhibits the lowest calorific value at 276.67±0.03kcal. Hidayah *et al.* (2019) determined the caloric value of corn grit and it was found to be 386.49 kcal.

Table 5: Calorific values composite flour (Corn Grit and Rice Husk)

Treatments	Calorific Values (kcal)
T_0	350.41±0.03^A
T_1	333.43±0.03^B
T_2	317.50±0.03^C
T_3	301.01±0.03^D
T_4	284.20±0.03^E
T_5	276.67±0.03^F

T_0= 100% Corn Grit
T_1= 90% Corn Grit + 10% Rice Husk
T_2= 80% Corn Grit + 20 % Rice Husk
T_3= 70% Corn Grit + 30 % Rice Husk
T_4= 60% Corn Grit + 40 % Rice Husk
T_5= 50% Corn Grit + 50% Rice Husk

3.3. Analysis of extruded breakfast cereals

3.3.1. Proximate Analysis of extruded Breakfast cereals

3.3.1.1. Crude moisture content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude moisture content. The findings of the extruded breakfast cereals analysis of variance for crude moisture content were very significant ($p \leq 0.01$). The average crude moisture content of

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

extruded breakfast cereals varied from 4.04±0.02 to 5.58±0.04%. Extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the highest moisture content at 5.58±0.04% while extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the lowest moisture content at 4.04±0.02%. Ratchaneeporn and Moongngarm, (2023) observed that the crude moisture content in corn grits, rice flour, and rice bran oil-based extruded multigrain puffed snacks and the moisture content ranged from 4.55 to 4.93%.

3.3.1.2. Crude fat content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude fat content. The findings of the extruded breakfast cereals analysis of variance for crude fat content were very significant ($p \leq 0.01$). The average value for the crude fat content of extruded breakfast cereals varied from 1.07±0.02 to 2.17±0.03%. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest fat content at 2.17±0.03% while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest fat content which was 1.07±0.02%. Similar findings were done by Renoldi *et al.* (2021) who prepared rice bran and corn-based snacks and the crude fat content was found 0.44 to 2.80%.

3.3.1.3. Crude protein content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude protein content. The findings of the extruded breakfast cereals analysis of variance for crude protein content were very significant ($p \leq 0.01$). The average values for crude protein content of extruded breakfast cereals varied from 4.29±0.02 to 7.18±0.02%. Extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the highest crude protein content at 7.18±0.02% while extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the lowest crude protein content at 4.29±0.02%. Amer and Rizk (2021) prepared extruded corn snacks and the amount of crude protein content in extruded corn snacks varied between 8.7 to 9.62%.

3.3.1.4. Crude ash content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude ash content. The findings of the extruded breakfast cereals analysis of variance for crude ash content were very significant ($p \leq 0.01$). The average value for crude ash content of extruded breakfast cereals varied from 0.73±0.02 to 4.31±0.02%. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest ash content at 4.31±0.02% while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest ash content which was 0.73±0.02%. According to Culet *et al.* (2023), the crude ash content in corn-based extrudates ranged from 0.57 to 1.60%.

3.3.1.5. Crude fiber content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude fiber content. The findings of the extruded breakfast cereals analysis of variance for crude fiber content were very significant ($p \leq 0.01$). The average value for crude fiber content of

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

extruded breakfast cereals varied from 0.96±0.02% to 12.08±0.02%. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest ash content at 12.08±0.02% while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest ash content which was 0.96±0.02%. According to Vector *et al.* (2023), the crude fiber content of broken rice and vegetable oil-based extruded breakfast cereals ranged from 0.58 to 1.15%.

3.3.1.6. Nitrogen-free extract (NFE) content of extruded breakfast cereals

Table 6 displayed the average values of extruded breakfast cereals for crude nitrogen-free extract content. The findings of the extruded breakfast cereals analysis of variance for nitrogen-free extract content were very significant ($p \leq 0.01$). The average value for nitrogen-free extract of extruded breakfast cereals varied from 73.11±0.04 to 84.48±0.05%. Extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the highest NFE content at 84.48±0.05% while extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the lowest NFE content at 73.11±0.04%. Ratchaneeporn and Moongngarm, (2023) observed that the nitrogen-free extract content in corn grits, rice flour, and rice bran oil-based extruded multigrain puffed snacks was 71.34 to 74.95%.

Table 6: Mean values for proximate composition of extrude breakfast cereals

Treatments	Proximate compositions (%)					
	Crude Moisture content	Crude Fat	Crude Protein	Crude Ash	Crude Fiber	NFE
T_0	5.58±0.04^A	1.07±0.02^F	7.18±0.02^A	0.73±0.02^F	0.96±0.05^F	84.48±0.05^A
T_1	5.27±0.02^B	1.18±0.03^E	6.28±0.02^B	0.93±0.03^E	3.35±0.03^E	82.99±0.04^B
T_2	5.03±0.02^C	1.47±0.02^D	6.14±0.02^C	1.37±0.02^D	5.63±0.02^D	80.36±0.04^C
T_3	4.97±0.02^D	1.73±0.02^C	5.29±0.04^D	2.37±0.02^C	8.56±0.03^C	77.08±0.03^D
T_4	4.36±0.02^E	2.07±0.02^B	5.04±0.03^E	3.04±0.02^B	10.07±0.03^B	74.32±0.04^E
T_5	4.04±0.02^F	2.17±0.03^A	4.29±0.02^F	4.31±0.02^A	12.08±0.02^A	73.11±0.04^F

T_0= 100% Corn Grit T_1= 90% Corn Grit + 10% Rice Husk

T_2= 80% Corn Grit + 20 % Rice Husk T_3= 70% Corn Grit + 30 % Rice Husk

T_4= 60% Corn Grit + 40 % Rice Husk T_5= 50% Corn Grit + 50% Rice Husk

3.3.2. Vitamins contents of extruded breakfast cereals

3.3.2.1. B_1 vitamin content of extruded breakfast cereals

Table 7 displayed the average values of extruded breakfast cereals for B_1 vitamin content. The findings of the extruded breakfast cereals analysis of variance for B_1 vitamin content were very significant ($p \leq 0.01$). The average value for B_1 vitamin content of extruded breakfast cereals varied from 0.01±0.01 to 0.10±0.01mg/100g. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest B_1 vitamin content at 0.10±0.01mg/100g while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest B_1 vitamin content at

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

0.01±0.01mg/100g. Figure 1 showed the effect of treatments on the level of B vitamin content in extruded breakfast cereals. Figure 1 showed an increasing trend because as the amount of rice husk increases the amount of B_1 vitamin content also increases. Umeohia *et al.* (2021) prepared extruded wheat snacks and the amount of B_1 vitamin in extruded wheat snacks was found 0.04mg/100g.

3.3.2.2. B_2 vitamin content of extruded breakfast cereals

Table 7 displayed the average values of extruded breakfast cereals for B_2 vitamin content content. The findings of the extruded breakfast cereals analysis of variance for B_2 vitamin content were very significant (p≤0.01). The average value for B_2 vitamin content of extruded breakfast cereals varied from 0.013±0.01 to 0.043±0.01mg/100g. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest B_2 vitamin content at 0.043±0.01mg/100g while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest B_2 vitamin content at 0.013±0.01mg/100g. Figure 1 showed the effect of treatments on the level of B vitamin content in extruded breakfast cereals. Figure 1 showed an increasing trend because as the amount of rice husk increases the amount of B_2 vitamin content also increases. Umeohia *et al.* (2021) prepared extruded wheat snacks and the amount of B_2 vitamin in extruded wheat snacks was found 0.03mg/100g.

3.3.2.3. B_3 vitamin content of extruded breakfast cereals

Table 7 displayed the average values of extruded breakfast cereals for B_3 vitamin content content. The findings of the extruded breakfast cereals analysis of variance for B_3 vitamin content were very significant (p≤0.01). The average value for B_3 vitamin content of extruded breakfast cereals varied from 0.54±0.01 to 0.63±0.01mg/100g. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest B_3 vitamin content at 0.63±0.01mg/100g while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest B_3 vitamin content at 0.54±0.01mg/100g. Figure 1 showed the effect of treatments on the level of B vitamin content in extruded breakfast cereals. Figure 1 showed an increasing trend because as the amount of rice husk increases the amount of B_3 vitamin content also increases. Umeohia *et al.* (2021) prepared extruded wheat snacks and the amount of B_3 vitamin in extruded wheat snacks was found 0.60 mg/100g.

3.3.2.4. B_6 vitamin content of extruded breakfast cereals

Table 7 displayed the average values of extruded breakfast cereals for B_6 vitamin content. The findings of the extruded breakfast cereals analysis of variance for B_6 vitamin content were very significant (p≤0.01). The average value for B_6 vitamin content of extruded breakfast cereals varied from 0.01±0.01 to 0.09±0.01mg/100g. Extruded breakfast cereals prepared with an equal proportion of corn grit and rice husk (T_5) exhibited the highest B_6 vitamin content at 0.09±0.01mg/100g while extruded breakfast cereals prepared with 100% corn grit (T_0), exhibited the lowest B_6 vitamin content at 0.01±0.01mg/100g. Figure 1 showed the effect of treatments on the level of B vitamin

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

content in extruded breakfast cereals. Figure 1 showed an increasing trend because as the amount of rice husk increases the amount of B_6 vitamin content also increases. Amer and Rizk (2021) prepared extruded corn snacks the amount of B_6 vitamin in extruded corn snacks was found to be 0.03mg/100g.

Table 7: Mean values for vitamin contents of extruded breakfast cereals

Treatments	Vitamins (mg/100g)			
	B_1	**B_2**	**B_3**	**B_6**
T_0	$0.01±0.01^E$	$0.013±0.01^C$	$0.54±0.01^C$	$0.01±0.01^E$
T_1	$0.03±0.01^D$	$0.027±0.01^B$	$0.56±0.01^B$	$0.03±0.01^{CD}$
T_2	$0.04±0.01^C$	$0.023±0.01^{BC}$	$0.57±0.01^B$	$0.04±0.01^D$
T_3	$0.06±0.01^{BC}$	$0.030±0.01^B$	$0.59±0.01^A$	$0.06±0.01^C$
T_4	$0.08±0.01^{AB}$	$0.033±0.01^{AB}$	$0.61±0.01^A$	$0.07±0.01^B$
T_5	$0.10±0.01^A$	$0.043±0.01^A$	$0.63±0.01^A$	$0.09±0.01^A$

T_0= 100% Corn Grit T_1= 90% Corn Grit + 10% Rice Husk
T_2= 80% Corn Grit + 20 % Rice Husk T_3= 70% Corn Grit + 30 % Rice Husk
T_4= 60% Corn Grit + 40 % Rice Husk T_5= 50% Corn Grit + 50% Rice Husk

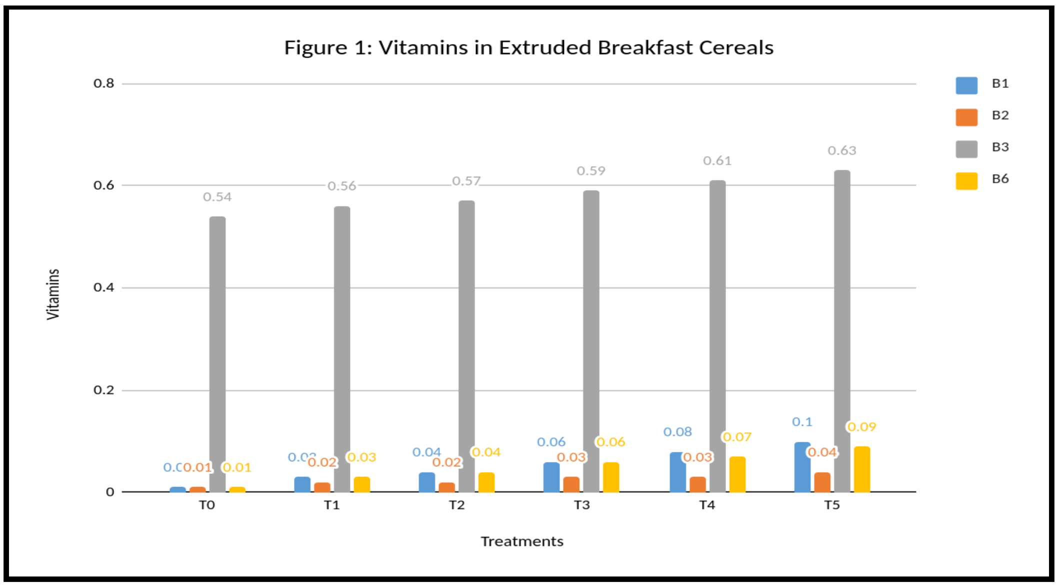

Figure 1: Vitamins in Extruded Breakfast Cereals

3.3.3. Sensory Analysis of extruded breakfast cereals

3.3.3.1. Appearance of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding appearance of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for appearance were very significant (p≤0.01). The average values of appearance of extruded breakfast cereals ranged from 7.29±0.03 to 8.66±0.03. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest appearance values 8.66±0.03 and treatment T_5 (50% corn grit and 50% rice husk) has lowest appearance values 7.29±0.03. These findings were similar with the results of Ozge *et al.* (2023) who

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

determined appearance score in red pepper pulp added extrudates and the value was 7.22.

3.3.3.2. Crispness of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding crispness of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for crispness were very significant ($p \leq 0.01$). The average values of crispness of extruded breakfast cereals ranged from 7.34±0.01 to 8.14±0.04. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest crispness values 8.14±0.04 and treatment T_0 (100% corn grit) has lowest crispness values 7.34±0.01. These findings were close to the results of Brighton *et al.* (2019) who determined the crispness score of corn based extruded snacks and the value ranged from 7.83 to 8.43.

3.3.3.3. Texture of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding texture of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for texture were very significant ($p \leq 0.01$). The average values of texture of extruded breakfast cereals ranged from 7.54±0.02 to 8.35±0.01. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest texture values 8.35±0.01 and treatment T_0 (100% corn grit) has lowest texture values 7.54±0.02. These results were comparable with the study of Joy *et al.* (2023) who determined the texture score of composite flour based extrudates and the value was 7.16.

3.3.3.4. Color of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding color of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for color were very significant ($p \leq 0.01$). The average values of color of extruded breakfast cereals ranged from 7.13±0.03 to 8.00±0.02. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest color values 8.00±0.02 and treatment T_0 (100% corn grit) has lowest color values 7.13±0.03. The current findings regarding color score of extruded breakfast cereals were similar with the findings of Nuttinee *et al.* (2023), he determined the color score of corn grits and pineapple stem starch-based extruded snacks and the value was 7.20.

3.3.3.5. Aroma of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding aroma of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for aroma were very significant ($p \leq 0.01$). The average values of aroma of extruded breakfast cereals ranged from 7.05±0.01 to 8.44±0.04. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest aroma values 8.44±0.04 and treatment T_5 (50% corn grit and 50% rice husk) has lowest aroma values 7.05±0.01. The current findings were comparable with the results of Jackson *et al.* (2015) who determined the aroma of yellow maize extrudates and the value of aroma ranged between 6.45 to 7.5.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

3.3.3.6. Flavor of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding flavor of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for flavor were very significant ($p \leq 0.01$). The average values of flavor of extruded breakfast cereals ranged from 7.00±0.01 to 8.23±0.02. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest flavor values 8.23±0.02 and treatment T_5 (50% corn grit and 50% rice husk) has lowest flavor values 7.00±0.01. The results of the current findings were similar with the study of Brighton *et al.* (2019) who determined the flavor score of corn based extruded snacks and the score ranged from 6.17 to 8.67.

3.3.3.7. Overall acceptability of extruded breakfast cereals

Table 8 displayed the average values of extruded breakfast cereals regarding overall acceptability of extruded breakfast cereals. The findings of the extruded breakfast cereals analysis of variance for overall acceptability were very significant ($p \leq 0.01$). The average value of overall acceptability of extruded breakfast cereals ranges between 7.66±0.02 to 8.54±0.01. Treatment T_4 contains (60% corn grit and 40% rice husk) has highest overall acceptability values 8.54±0.01 and treatment T_0 (100% corn grit) has lowest overall acceptability values 7.66±0.02. Current findings were similar with the study of Brighton *et al.* (2019), he determined the overall acceptability score of corn based extruded snacks and the value ranged from 6.83 to 8.35.

Table 8: Mean Values of sensory evaluation of extruded breakfast cereals

Treatments	Appearance	Crispiness	Texture	Color	Aroma	Flavor	Overall acceptability
T_0	7.33±0.02^C	7.34±0.01^E	7.54±0.02^F	7.13±0.03^D	7.45±0.03^D	7.21±0.03^E	7.66±0.02^E
T_1	7.39±0.02^D	7.48±0.02^D	7.69±0.02^D	7.21±0.04^C	7.33±0.02^C	7.29±0.02^D	7.73±0.03^D
T_2	7.43±0.03^E	7.61±0.03^C	8.00±0.03^C	7.30±0.02^F	7.20±0.03^E	7.32±0.01^C	7.89±0.02^B
T_3	8.33±0.03^B	8.21±0.02^B	8.15±0.03^B	7.42±0.03^B	8.33±0.02^B	7.94±0.04^B	8.40±0.01^A
T_4	8.66±0.03^A	8.69±0.03^A	8.35±0.01^A	8.00±0.02^A	8.44±0.04^A	8.23±0.02^A	8.54±0.01^C
T_5	7.29±0.03^F	7.93±0.04^F	8.03±0.01^E	7.66±0.01^E	7.05±0.01^F	7.00±0.01^F	7.78±0.04^F

T_0= 100% Corn Grit T_1= 90% Corn Grit + 10% Rice Husk
T_2= 80% Corn Grit + 20 % Rice Husk T_3= 70% Corn Grit + 30 % Rice Husk
T_4= 60% Corn Grit + 40 % Rice Husk T_5= 50% Corn Grit + 50% Rice Husk

4. CONCLUSION

The study successfully developed nutritionally enhanced extruded breakfast cereals by incorporating industrial waste rice husk, focusing on increasing B vitamin content. As the amount of rice husk increases, the B vitamin content level rises accordingly. The optimized formulation, containing 40% rice husk and 60% corn grits has the ability to provide great nutrient levels with high scores for sensory attributes. The findings suggest that short-term high-temperature extrusion is effective in retaining heat-labile B vitamins, thus providing a viable method for producing nutrient-dense, consumer-preferred

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

breakfast cereals. This approach offers a sustainable use of agricultural byproducts and meets the growing demand for convenient and healthy foods.

References

1) AACC. 2016 Approved methods of American association of cereal chemists (11th ed.). St Paul, MN: AACC International.

2) Amer, S. A. and A. E. Rizk. 2022. Production and evaluation of novel functional extruded corn snacks fortified with ginger, bay leaves and turmeric powder. Food Production, Processing and Nutrition. 4(1):1-17.

3) Antun, J. 2017. Optimisation of Extrusion Variables for the Production of Corn Snack Products Enriched with Defatted Hemp Cake. Czech Journal of Food Sciences.35:6.

4) Aryane, R.O., A. Chaves, E. Resende, K. Oliveira, M. Costa, I. Careli-Gondim and M. Caliar. 2020. Physicochemical, microbiological and sensory characteristics of snacks developed from broken rice grains and turmeric powder. International Journal of Food Science and Technology. 55(7):2719-2729.

5) Ashwar, A.B., G.A. Asir and A.A. Mudasir. 2021. Encapsulating probiotics in novel resistant starch wall material for production of rice flour extrudates. LWT - Food Science and Technology. 140:e110839.

6) Aslam, A. and B. Junaid. 2008. HPLC analysis of water-soluble vitamins (B_1, B_2, B_3, B_5, B_6) in in vitro and ex vitro germinated chickpea (*Cicer arietinum L*.). African Journal of Biotechnology. 7:14.

7) Athar, N., A. Hardacre, G. Taylor, S. Clark, R. Harding and J. McLaughlin. 2006. Vitamin retention in extruded food products. Journal of Food Composition and Analysis. 19(4):379-383.

8) Brighton, J. and V. Nithyalakshmi. 2019. Development and Quality Evaluation of Corn Based Extruded Snacks Incorporating Goat Offal Meat Powder. International Journal of Current Microbiololgy Appllied Sciences. 8(8):1910-1914.

9) Chauhan, A., J.K. Sahu, N. Jaiswal, K. Kumar, A. Agarwal, K. Kaur, and M. Singh. 2019. Prevalence of autism spectrum disorder in Indian children: A systematic review and meta-analysis. Neurology India. *67*(1):100.

10) Culet, U., A. S.E. Iulia, M. Mihaela, S. Erban, C. Eugen and B. Nastasia. 2023. Corn Extrudates Enriched with Health-Promoting Ingredients: Physicochemical, Nutritional, and Functional Characteristics. Processes. 11:1108.

11) Elkatry, H.O., H.S. El-Beltagi, A.R. Ahmed, H.I Mohamed, H.H. Al-Otaibi, K.M. Ramadan and M.A. Mahmoud. 2023. The potential use of Indian rice flour or husk in fortification of pan bread: assessing bread's quality using sensory, physicochemical, and chemometric methods. Frontiers in Nutrition. 10:913-920.

12) Fărcaș, A.C., S.A. Socaci, O.L. Nemeș, T.E. Pop, M. Coldea and E.S. Biriș-Dorhoi. 2022. An Update Regarding the Bioactive Compound of Cereal By-Products: Health Benefits and Potential Applications. Nutrients. 14:3470.

13) Hidayah, N., R.S. Adiandri, E. Rahayu and S. Nugraha. 2019. Evaluation of corn grit quality from farmer-scale trial production. In IOP Conference Series: Earth and Environmental Science. 309(1):12-18.

14) Jackson, N. and I. Gabriel. 2015. Okafor Effect of Incorporation of Amaranth Leaf Flour on the Chemical, Functional and Sensory Properties of Yellow Maize/Soybean Based Extrudates. Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 9(7):31-40.

15) Joy, L.P., M. Leonara, C.F. Ana Júlia, O. Valéria, S. Hércia and M. Duarte, A. Luciana, W. Carlos, C. Piler, H. Mária and R. Frederico. 2023. Evaluation of the physical, chemical, technological, and sensorial properties of extrudates and cookies from composite sorghum and cowpea flours. Foods. 12(17):3261.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 57 Issue: 09:2024
DOI: 10.5281/zenodo.13801707

16) Jozinovic, A., D. Ackar, S. Jokic, J. Babic, J.P. Balentic, M. Banozic and D. Subaric. 2018. Optimisation of extrusion variables for the production of corn snack products enriched with defatted hemp cake. Czech Journal of Food Sciences. 35(6): 507-516.

17) Kantrong, H. 2022. Effects of extrusion temperature and puffing technique on physical and functional properties of purpled third-generation snack after heat treatment. Journal of Food Science and Technology. 59(6):2209-2219.

18) Khantam,P. Linsaenkart, T. Chaitep, P. Jantrawut, C. Chittasupho, P. Rachtanapun, K. Jantanasakul won,Y. Phimolsiripol, S.R. Sommano, C. Prom-U-Thaiand S. Jamjod. 2022. Antioxidation, anti-inflammation, and regulation of *SRD5A* gene expression of *Oryza sativa* cv. bue Bang 3 CMU husk and bran extracts as androgenetic alopecia molecular treatment substances. 2(4):88.

19) Nitu, k. 2023. Effect of extrusion technology in nutritional quality of food: A review. The Pharma Innovation Journal. 12(5):1884-1892.

20) Nnadiukwu, U.C., E.N. Onyeike, C.C. Lkewuchi and K.C. Patrick-Iwuanyanwu. 2023. Phytochemical and Nutrient Composition of Rice Husks. Tropical Journal of Natural Product Research. 7(2):2457-2463.

21) Nuttinee T., H. Sornsawan, K. Chutikarn, S. Nongnuch, B. Natt, S. Natdanai, S.M. Siwaporn, A. Taweechai, P. Jukkrapong and R. Wongsagonsup. 2023. Physicochemical and sensory properties of corn grits and pineapple stem starch-based extruded snacks enriched with oyster mushroom powder. International Journal of Food Science and Technology. 58(3):1528-1540.

22) Özge, Y., C. Cagla Caltinoglu and A. Ilkay. 2022. Enhanced Bioaccessibility by Extrusion Process and Quality Parameters of Red Pepper Pulp Added Extrudates. Gıda. 47(1):15-24.

23) Paterne, R.O.U.G.B.O., D.O.U.E. Gladys, S.E.H.A. Bernard and E.B. Anicet. 2019. Comparative study on proximate, mineral and anti-nutrient content of composite roasted corn flour with its traditional roasted corn counterpart for homemade complementary foods. Asian Food Science Journal. 9(1):1-9.

24) Ratchaneeporn P. and M. Anuchita. 2023. Effect of rice flour to corn grits ratio and rice bran oil addition on starch digestibility profiles and properties of extruded multigrain puffed snacks. International Journal of Food Science and Technology. 1:1-4.

25) Renoldi, N., S.H. Peighambardoust and D. Peressini. 2021. The effect of rice bran on physicochemical, textural and glycaemic properties of ready-to-eat extruded corn snacks. International Journal of Food Science and Technology. 56(7): 3235-3244.

26) Saraswathi, D., R. Renu and M. Srinivas. 2018. Development and quality evaluation of pumpkin seeds and flaxseeds powder incorporated biscuits. International Journal of Food Science and Nutrition 3(2):78-83.

27) Sohrab, S., M. Masha and F. Asghar. 2020. Effects of particle size and moisture content of maize grits on physical properties of expanded snacks. Journal of Texture Study.1-14.

28) Tas, A.A. and A.U. Shah. 2021. The replacement of cereals by legumes in extruded snack foods: Science, technology and challenges. Trends Food Science and Technology. 116:701-711.

29) Umeohia, U.E. and G.I. Okafor. 2021. Production and evaluation of extruded snacks from Sourghum (*Sorghum bicolor l. Moench*), soybean (*Glycine max (l.) Merr.*) And carrot (*Daucus carota subsp. sativus*). International Journal of Food Science and Nutrition. 6(3):72-77.

30) Uzoamaka C. 2023. Phytochemical and Nutrient Composition of Rice Husks. Tropical Journal of Natural Product Research. 7:2.

31) Vector, G.S., B. Daniel, R.P. Ana, M.A. Juliana and S.J. Caroline. 2023. Sustainable production of naturally colored extruded breakfast cereals from blends of broken rice and vegetable flours Author links open overlay. Food Research International. 172:113078.