Volume 2 Issue 1 | PDF 108 | Pages 6
Edelweiss: Food Science and Technology
Research Article ISSN: 2765-8821

Evaluation of Functional, Nutritional and Bioactive Properties of Gluten Free Muffins Utilizing Industrial By-Products of Baby Corn

Kamaljit Kaur* **and Anchit Sharma**

Affiliation: Department of Food Science and Technology, Punjab Agricultural University Ludhiana, Punjab, India

***Corresponding author:** Kamaljit Kaur, Department of Food Science and Technology, Punjab Agricultural University Ludhiana, Punjab, India, Email: kamalbhella@pau.edu

Citation: Kaur K and Sharma A. Evaluation of functional, nutritional and bioactive properties of gluten free muffins utilizing industrial by-products of baby corn (2021) Edelweiss Food Sci Tech 2: 1-6.

Received: Jul 12, 2021
Accepted: Aug 22, 2021
Published: Aug 29, 2021

Abstract

This study was planned to utilize by-products of baby corn, which was powdered upon drying. Different formulations containing baby corn: defatted soya: plantain: finger millet flours at 10:65:20:5, 15:55:20:10, 20:45:20:15 and 25:35:20:20 were prepared and analyzed for functional, nutritional and bioactive properties of the blended flours and muffins. The outcomes indicated that incorporation of baby corn flour had enhanced functional and pasting properties of the blended flours. The addition of baby corn flour increased the antioxidant properties and metal chelating activity of blended flours. The incorporation of baby corn flour had contributed better retention of antioxidant potential during baking as muffins with 25% baby corn showed more increase in antioxidant properties than 10% baby corn muffins. Hardness and specific volume of muffins increased, while total phenol content decreased significantly with increment in the level of baby corn flour. On the basis of sensory analysis muffins prepared with 20% level of baby corn flour was selected best. This study concluded that by-products of baby corn can be utilized for development of gluten free muffins with better nutrition and bioactive properties.

Keywords: Antioxidant properties, Baby corn flour, Functional properties, Plantain flour and Total phenols.

Abbreviations: BCF-Baby Corn Flour, DSF-Defatted Soybean Flour, FMF-Finger Millet Flour, FC-Foam Capacity, FS-Foam Stability, GAE-Gallic Acid Equivalent, NEB-Non Enzymatic Browning, OAC-Oil Absorption Capacity, PF-Plantain Flour, RVA-Rapid Visco Analyzer, OD-Optical Density

Introduction

Surging incidences of celiac diseases lead to increase in demand of gluten-free products. People with wheat allergies and wheat intolerances use gluten-free foods to maintain their quality of life. It is characterize as a strong immune response to certain amino acid sequences present in the gliadin fractions of oats, wheat, barley and rye. The consumption of gluten can damage the intestines, cause bloating and abdominal pain, weight loss, chronic diarrhea, fatigue and low weight in babies as well malabsorption of essential nutrients that lead to malnutrition. The devotion to a gluten-free diet is still an effective treatment against celiac disease during the entire life of patients. Greater awareness of celiac disease throughout the world has leads to growing demand for gluten-free products such as cookies, bread, pasta and cakes [1-4].

Baby corn is rich in vitamins like riboflavin, ascorbic acid, fiber and potassium. It can be compared with different vegetables like cauliflower, brinjal, tomato, and cucumber at nutritional level. It had been demonstrated that it adds exceptionally unique flavor to various dishes like pickle, soups, servings of mixed greens and a few Chinese delights. In Chinese, American and European restaurants these are widely used as canned or stir fried vegetable and used as boiled in salt water and can be served with combination of rice, spices and herbs [5]. Baby corn by-products were used by Singh and Kaur (2020) [6] to prepare baby soup mix to alleviate the problem of postharvest losses of an industry. Plantain flour contains starch content 73.4%, resistant starch 17.5% and approximately 14.5% dietary fiber. Due to the high content of these useful ingredients the regular intake of plantain flour can have beneficial effects for human health [7]. Green unripe bananas have antimicrobial properties and have been used as medicine in ancient India and China. Apart from its food applications, green bananas are not consumed raw. These are peeled, sliced and then either dehydrated, fried, cooked or boiled before consumption [8]. During the recent years, the demand of green dried bananas has increased both within and outside the country. Soybean contains all the crucial amino acids that are essential for healthiness. The protein content of soybeans is about 4 times more than wheat and 6 times more than rice. Soybean is also rich in calcium, phosphorus and vitamins D, A, C and B [9]. Outer cover of seed is rich in phytochemicals such as polyphenols, dietary fiber and is also very rich in minerals especially calcium [10]. Fried et al. (2018) [11] expressed that soybeans as food are flexible and a rich wellspring of basic nutrients.

They are amazing source of good-quality protein, equivalent to other protein nourishments, and reasonable for all ages. Soybeans give an elective wellspring of protein for individuals who are oversensitive to milk protein. Soy protein is profoundly edible (92 to 100%) and contains all fundamental amino acids. Millet grains are better than rice and wheat because of fundamental amino acids, for example, methionine and tryptophan [12]. Finger millet is a significant well-spring of dietary starches for a huge segment of society having a place with millet developing territories. Withstanding to this, finger millet also contain few micronutrients for example, lignin, manganese and niacin etc. which are significant for human beings. The objective of this study was to prepare gluten free muffins by exploring the utilization of baby corn by-products in the form of flour along with defatted soy flour, plantain flour and finger millet flour. Flour blends and muffins were evaluated for functional, nutritional and bioactive properties.

Materials and Methods

Baby corn cut pieces were procured from Field Fresh Foods Pvt. Ltd. Ladhowal, Ludhiana and flour was made. Fresh green bananas were purchased from nearby market and flour was made. Finger millet flour and defatted soybean flour were procured from the nearby market. Chemicals and reagents used in the investigation were of analytical grade. Basic ingredients for muffins preparation were purchased from local market. Cut pieces of baby corn were dried at 50 ± 2ºC for a period up to constant weight. The dried product was reduced to a fine powder in a laboratory scale mill.

Preparation of Plantain Flour (PF): Plantain was procured from local market and then flour was made. Plantain flour was prepared according to the method described by Ovando-Martinez et al. (2009) [13] with some modifications. The fruits were peeled, cut into slices about 1cm thickness and then rinsed in citric acid solution (0.3% w/v) to reduce enzymatic browning reactions. These slices were dried overnight in a convection drier at 50 ± 2˚C then milling was done in lab, stored at 25˚C in sealed plastic container.

Proximate analysis: The flours and flour blends were investigated for moisture, ash, and protein, fat and crude fiber as indicated by standard AOAC (2012) [14] procedures.

Functional Properties

Water absorption index: Water absorption capacity was evaluated as per Singh et al. (2017) [15] by taking 3g flour sample in a pre-weighed 50mL centrifugation tube and added 30 mL deionized water to it and allow the flour to absorb water for 30 min with gentle stirring, It was then centrifuged (3500 rpm, 30 min). Supernatant obtained was collected and weighed. The water absorption index was expressed as a percentage.

Oil Absorption index: Oil absorption capacity was evaluated as per Singh et al. (2017) [15] by taking 3 g flour sample in a pre-weighed 50 ml centrifugation tube and added 30 ml refined soybean oil to it and allow the flour to absorb water for 30min with gentle stirring followed It was then centrifuged (3500 rpm, 30 min) and decanting the oil. The increase in the weight was evaluated by weighing the centrifugation tube and expressed as percentage.

Foaming Capacity and Stability

Foaming capacity and foam stability was determined as per Singh et al. (2017) [15] by taking 2 g flour sample in a 500 ml beaker and added 100 mL deionised water to it and suspension was blended. for 1 min and contents were transferred to 250 ml measuring cylinder and foaming capacity was determined in percentage as per following equation. Foam stability was evaluated by noting the decline in the volume of foam after every 10 min interval of 60 min.

Bulk density: Bulk density was determined by using method as described by Singh et al. (2017) [15] 20 g of sample was taken in a 100ml measuring cylinder and tapping was done. The tapping volume and weight of sample was noted and density was expressed as the ratio of mass by volume.

Pasting properties

Pasting properties of muffins were determined using Rapid Visco Analyzer (RVA) model Starch Master 3 (Newport Scientific, Wrrie wood, Australia). Milled sample was used for analysis. The following procedure was followed in sequence to determine the properties of starch [16]. Start the RVA equipment and it is allowed to heat up for 30 min before the experiment. 3 g of the sample was weighed on the canister and addition of water (25 ml) is done. Paddle was kept in the canister; blade was moved up and down 10 times till it uniformly mixes. RVA instrument was pre-adjusted followed by attachment of the canister and the motor power is lowered down to initiate the measurement cycle. Profile 1 was selected and when the test cycle completes, canister was removed and reading was recorded.

Muffin Formulation and Processing

For making muffins, the formula according to Jyotsna et al. (2011) [17] was used with slight modifications. Initial trials were conducted for preparation of muffins by taking various levels of baby corn flour, plantain flour, finger millet flour and defatted soybean flour. Based upon muffin making characteristics, four formulations were selected i.e. Mixture of baby corn flour: plantain flour: finger millet flour: defatted soya bean flour (10:20:5:65), (15:20:10:55), (20:20:15:45) and (25:20:20:35) and these formulations were compared with each other for the best quality of muffins.

Proximate analysis: The Muffins were investigated for moisture, ash, and protein, fat and crude fiber as indicated by standard AOAC (2012) [14] procedures.

Specific Volume of Muffins by Rapeseed Displacement Method

The muffin volume was measured by rapeseed displacement. Muffins were weighed and placed in a pan. After the rapeseeds are poured over the muffins, those seeds that were displaced by muffin measured as the volume of the muffins AACC (2000) [18] and specific volume was measured by dividing volume of muffin by its weight.

Bioactive Properties of Muffins

Antioxidant Activity: Method of Kaur et al. (2020) [19] was used to determine antioxidant activity. Extract 1g of sample with 50 ml of 80 percent methanol for 2hr, filter it and again extract for 1hr with same amount and strength of methanol. It was then filtered and made volume to 100 ml with methanol. To 1 ml of extract, 1 ml of tris buffer and 2 ml of DPPH was added. The sample was then incubated at room temperature in dark for 30mins. The control samples were prepared without incubation and methanol was taken as a blank. The Optical Density (OD) was calculated at 515 nm.

Total Phenols: Total phenols were calculated by using method described by Kaur et al. (2020) [19]. Results were expressed as gallic acid equivalent (GAE) mg/ 100 g of Dry Weight (DW) of powder.

Metal Ion Chelating Activity

Ferrous ion chelating Activity was determined as per Kaur et al. (2020) [19]. 0.5g flour was extracted with 75% methanol (v/v) using orbital shaker for 2 hour. Sample was centrifuged at 3000 rpm and 50 ml volume was made with 75% methanol. 1 mL methanolic extract was taken in test tube and added 1mL 0.1mM FeSo4, followed by addition of 1 mL 0.25 mM ferrozine solution and allowed to stand for 10 minutes. OD was measured at 562 nm.

Non Enzymatic Browning (NEB) Index

Non Enzymatic Browning Index of the samples was revealed by Sharma and Gujral (2011) [20]. The browning index (ΔA) was determined as: ΔA=Absorbance sample (420 nm)-Absorbance Sample (550 nm).

Determination of crust and crumb color: Estimation of the muffin color was done with a Hunter Labscan II colorimeter, and outcomes were communicated by CIELAB framework. The estimations were performed through a 6.4 mm diameter diaphragm containing an optical glass. The L^*(lightness to darkness), a^*(redness to greenness), b^*(yellowness to blueness) values were recorded. Each muffin was cut in two halves to measure the crumb color and crust color all the measurements were made by placing the sample directly on the colorimeter diaphragm.

Textural Properties of Muffins

The compression force of muffins was analyzed by CT3 Texture Analyzer [21]. Muffins were subjected to double compression cycle. Hardness, cohesiveness, gumminess, chewiness and springiness of the crumb were calculated for texture profile analysis. The muffins were exposed to compression test under 50% target deformation, 1mm/s test and post-test speed; 5kg trigger load, and 5 second recuperation time. Every muffin was cut with a steel blade, for 30 × 30 × 30 mm (l × w × h).

Sensory Evaluation of Muffins

Sensory quality of muffins was evaluated by hedonic rating test using nine point hedonic scales. Sensory analysis was carried out in individual air-conditioned booths with white light. Plain water was provided for cleansing the palate. Hedonic scale of nine numerical values indicates the range of likes from extremely like to extremely dislike. In Hedonic test, muffins were served to the 10 panellists. Muffins were evaluated for appearance, taste, texture, color and overall acceptance [22].

Statistical Analysis

SPSS software (Version 20.0, IBM Corporation) was used at $p< 0.05$ using one-way ANOVA. Values were represented as mean ± standard deviation.

Result and Discussion

Physicochemical analysis of flours and flour blends: Baby corn, plantain, finger millet and defatted soy flour were evaluated for moisture, crude protein, crude fat, crude fiber, ash and carbohydrate content. Defatted soy flour contained protein content of 52.1% which was higher than other flours and fat content of 0.79 % **(Table 1)**. This was similar to findings of Taghdir et al. (2016) [9]. The average protein content of baby corn was 16.94 % and fat content was 1.69%. Similar results were reported by Kaur et al. (2018) [23]. Moisture content of blends was increased with increase in proportion of baby corn flour from 8.6% to 10.7% (Table 1) According to El Wakeel (2007) [24] moisture content less than 10% inhibits the growth of microorganisms. Protein content of blends was decreased with increased proportion of baby corn flour, same pattern was observed with ash content of blends. There is no significant trend of increases and decrease of crude fiber content of blends was observed. Carbohydrates content of blends was also increased with increased proportion of baby corn flour. Thus with increased levels of baby corn flour moisture, fat and ash content of flour mix increased and similar trend was reported by Jauharah et al. (2014) [25] for muffins prepared with young corn flour.

Functional and Pasting Properties of Flours and Flour Blends: Functional and pasting properties of individual flours and flour blends are summarized in **Table 2**. Baby corn flour had highest water absorption capacity (287.7%) than that of other flours. Proteins and various hydrophilic carbohydrates have high affinity for water molecules [26]. Thus absorption increased as the extent of baby corn flour increased in flour mixes [6]. Baby corn flour exhibited higher oil absorption capacity (216.89%) in comparison to other flours. Oil absorption capacity is an essential index as it alters mouth feel and retain flavor in products [26]. With increased extent of baby corn flour oil absorption capacity of flour blends were also increased.

Similar results were reported by Singh and Kaur (2020) [6] for baby corn soup mix with increased level of baby corn flour. Baby corn flour had higher foam capacity (60.28%) than other flours. The Foam Stability (FS) is the ability of flour to settle against mechanical and gravitational stresses. Foaming stability of defatted soy flour (64.99%) was found significantly higher where as baby corn flour had lowest foam stability (14.2%) which results in decreased foam stability of flour blends with increased proportion of baby corn flour. High bulk density of flours suggests their suitability for application in food preparations [26]. Baby corn flour had highest bulk density (396.7 kg/m^3) as a result bulk density of flour blends were also increased with increased proportion of baby corn flour. Pasting properties play a principle role in the selection of flours as a binder, thickener or any other use.

Sample	(%) Moisture	(%) Crude Protein	(%) Crude Fat	(%) Ash	(%) Crude fibre	(%) Carbohydrates
BCF	9.66 ± 0.41^c	16.34 ± 0.39^b	1.69 ± 0.17^b	4.91 ± 0.14^b	20.35 ± 0.13^a	67.38 ± 0.51^c
PF	8.8 ± 0.08^b	3.0 ± 0.03^d	1.4 ± 0.05^c	3.14 ± 0.2^c	1.33 ± 0.34^d	83.6 ± 0.52^a
FMF	12.06 ± 0.21^a	7.30 ± 0.05^c	2.73 ± 0.06^a	2.21 ± 0.11^d	3.03 ± 0.06^c	75.6 ± 0.23^b
DSF	8.64 ± 0.02^d	59.2 ± 0.37^a	0.79 ± 0.03^d	6.43 ± 0.27^a	3.29 ± 0.47^b	32.1 ± 0.04^d
A	8.63 ± 0.10^{0d}	41.96 ± 0.01^a	1.09 ± 0.02^d	5.39 ± 0.10^a	4.58 ± 0.26^d	43.29 ± 0.12^d
B	9.1 ± 0.02^c	36.8 ± 0.100^b	1.23 ± 0.01^c	5.1 ± 0.02^b	6.41 ± 0.31^a	47.84 ± 0.156^c
C	9.8 ± 0.10^b	31.8 ± 0.05^c	1.37 ± 0.05^b	4.83 ± 0.10^c	5.27 ± 0.45^b	52.62 ± 0.014^b
D	10.7 ± 0.03^a	26.8 ± 0.03^d	1.51 ± 0.10^a	4.54 ± 0.10^d	5.09 ± 0.10^c	57.55 ± 0.235^a

Note:*Expressed on dry matter basis Values are expressed as Mean ± standard deviation (n=3) Means with different superscripts in a column differ significantly at p< 0.05 by Tukey's test. BCF=Baby Corn Flour, PF=Plantain Flour, FMF=Finger Millet Flour, DSF=Defatted Soybean Flour Formulation A=10 BCF: 20 PF: 5FMF: 65DSF Formulation B=15 BCF: 20 PF: 10FMF: 55DSF. Formulation C=20 BCF: 20 PF: 15FMF: 45DSF Formulation D=25 BCF: 20 PF: 20FMF: 5DSF.

Table1: Physiochemical analysis of flours and flour blends.

Sample	BCF	PF	FMF	DSF	A	B	C	D
(%) WAC	287.7 ± 1.83^a	$262.53b \pm 0.58^b$	140.7 ± 3.04^c	131.1 ± 0.95^d	152.7 ± 1.67^d	161.23 ± 1.20^c	169.89 ± 0.96^b	178.50 ± 0.65^a
(%) OAC	216.89 ± 2.88^a	$192.6b \pm 0.12^b$	141 ± 0.23^c	120.25 ± 0.54^d	134.47 ± 1.28^d	140.46 ± 1.02^c	146.75 ± 0.73^b	152.37 ± 0.70^a
(%) FC	60.28 ± 0.57^b	$21.5c \pm 0.10^c$	1.96 ± 0.20^d	51 ± 0.12^a	22.43 ± 0.992^a	27.47 ± 0.880^b	31.32 ± 0.623^c	35.1 ± 1.02^d
(%) FS	14.24 ± 0.41^d	$16.42a \pm 0.02^a$	20 ± 0.23^c	64.99 ± 0.14^b	59.34 ± 0.81^a	54.52 ± 0.90^b	49.69 ± 1.21^c	45.20 ± 1.05^d
BD (kg/m3)	396.7 ± 0.45^a	$196c \pm 0.52^c$	245 ± 0.32^b	289 ± 0.056^d	417 ± 0.11^d	473 ± 0.010^c	537 ± 0.01^b	601 ± 0.01^a
Pasting temp(°C)	50.27 ± 0.10^d	83.3 ± 0.23^a	$71.11^c \pm 0.55^c$	78.35 ± 0.33^b	73 ± 0.12^a	75.6 ± 0.21^b	79.1 ± 0.004^c	82.4 ± 0.85^d
Peak viscosity(Cp)	7006 ± 0.011^a	6255.25 ± 0.50^b	1523.0 ± 0.22^c	437.5 ± 0.238^d	1392 ± 0.45^a	1279 ± 0.54^b	1090 ± 0.47^c	936 ± 0.96^d
Hold viscosity (cP)	3306 ± 0.12^a	3107.6 ± 0.23^d	490.88 ± 0.46^b	295.5 ± 0.05^c	720 ± 0.85^a	659.57 ± 0.31	575 ± 0.65^c	508 ± 0.42^d
Final viscosity (cP)	5883 ± 0.102^a	5461.33 ± 0.12^d	2061.3 ± 0.145^b	586.90 ± 0.14^c	1551 ± 0.112^a	1456 ± 0.45^b	1272 ± 0.75^c	1142 ± 0.14^d
Breakdown viscosity(cP)	3707 ± 0.14^a	3148.88 ± 0.48^d	1032.33 ± 0.14^b	142.15 ± 0.14^c	672 ± 0.457^a	619.5 ± 0.78^b	515 ± 0.15^c	428 ± 0.15^d
Setback viscosity (cP)	2577 ± 0.78^a	1802.67 ± 0.46^c	1571.0 ± 0.0^b	292.56 ± 0.45^d	831 ± 0.50^a	796.5 ± 0.05^b	697 ± 0.45^c	634 ± 0.36^d

Note: Expressed on dry matter basis, Values are expressed as Mean ± standard deviation (n = 3) Means with different superscripts in a column differ significantly at p< 0.05 by Tukey's test.

Table 2: Functional and pasting properties of flours and flour blends.

These properties depend upon rigidity of starch granules that affect swelling potential of starch granules and leaching of amylose in the solution [16]. PV recorded in this study was 7006cP for baby corn flour, 6255 cp for plantain flour, 1523cP for finger millet flour and 437.6 cp for defatted soybean flour. The higher PV of baby corn flour shows its greater ability to hold water and swelling ability without bursting. PV of flour blends increased with increased proportion of baby corn flour. High peak viscosity plays an important role in the preparation of food products like soups, cakes, muffins, biscuits, porridges, stiff dough products [27].

Final viscosity demonstrates the capacity of flour to form paste and was varied from 1551(Formulation A) to 1142 cp (Formulation D). Same results were for hold, final, breakdown viscosity and setback viscosity. The results were similar to the earlier studies by Singh and Kaur (2020) [6], who studied the pasting properties of baby corn powder and its incorporation in baby corn soup mix at different levels.

Proximate Composition of Muffins: Proximate composition of muffins is summarized in **Table 3**. The ash content of muffins increased with increased levels of baby corn and this increase might be due to the high mineral content of baby corn flour i.e., calcium, phosphorus [28]. Thus according to nutritional point, baby corn flour has ability to improve mineral content of food products. The moisture content was ranged from 23.73% (Formulation A) to 32.07% (Formulation D). One of the main constitute in muffins formulation is sucrose which is mainly contributed by use of sugar and also by baby corn flour. Subsequently in muffins with more baby corn concentration, moisture is higher because of high sucrose content [25]. The fat content of Formulation A was found to be 9.7% and it decreased to 8.20% in Formulation D. There is no significant trend of increase and decrease of crude fiber content of muffins. The protein content of muffins decreased from 16.7 to 12.50%.

This might be explained by higher protein content of defatted soy flour (52.1%), as concentration of defatted soy flour decreases in muffins (65 to 35%). As per other investigation it is reported that protein content of biscuits were higher, because of defatted soy flour [29]. Carbohydrates content of muffins decreased with increased concentrations of baby corn flour (50.5 to 44.6%). Lim (2013) [30] also observed a decrease in carbohydrate content of bread sample with increased concentration of baby corn flour. Jauharah et al. (2014) [25] also reported increase in moisture, ash, fat and carbohydrates content of muffins incorporated with young corn powder.

Specific volume and color analysis of muffins

The specific volume and color values of gluten free muffins are presented in **Table 4**. Specific volume was highest for formulation D (2.58 g/ml) and lowest for formulation A (2.48 g/ml). Singh et al. (2015) [31] reported that this increase might be due to the increase in batter viscosity. Increased in specific volume could be due to protein network created due to incorporation and retention of air by BCF during blending and heating. The color of the muffins decreased in terms of lightness (L^*) and yellowish (b^*) while increase in a^* (redness) with increased proportion of BCF was observed. Maillard browning and sugar caramelization produced brown pigments during the baking which were responsible for brown color during baking [32].

Texture and bioactive properties of muffins

Maximum force required for the first compression cycle is defined as hardness of product, while cohesion is the resistance of the food structure and the property of a product to adhere itself. Energy required to chew the food piece is measure as cohesiveness [21]. Based on observation, it was observed that muffins with higher concentration of BCF crumbled easily **(Table 5)**. Therefore to avoid the disintegration of the product during chewing it is better to have a high value of cohesion. Gumminess correlates with cohesion and hardness and is defined as cohesion multiplied by hardness. An increase in hardness was observed for samples with increase in proportion of baby corn flour, which ranges from 16.99 to 31.02N. Low fat content of baby corn flour might be possible cause of increase in hardness.

Product code	(%) Moisture	(%) Crude Protein	(%) Crude Fat	(%) Ash	(%) Crude fibre	(%) Carbohydrate
A	23.7 ± 0.24^d	16.7 ± 0.022^a	8.20 ± 0.01^d	1.07 ± 0.005^a	3.6 ± 0.36^d	50.5 ± 0.034^d
B	25.7 ± 0.26^c	15.1 ± 0.16^b	8.5 ± 0.05^c	1.1 ± 0.025^b	5.5 ± 0.264^a	49.6 ± 0.351^c
C	29.7 ± 0.25^b	13.6 ± 0.21^c	9.13 ± 0.06^b	1.2 ± 0.021^c	4.3 ± 0.20^b	46.27 ± 0.336^b
D	32.0 ± 0.14^a	12.5 ± 0.10^d	9.7 ± 0.05^a	1.37 ± 0.41^d	5.73 ± 0.15^c	44.46 ± 0.40^a

Note:*Expressed on dry matter basis Values are expressed as Mean ± standard deviation (n=3) Means with different superscripts in a column differ significantly at p< 0.05 by Tukey's test.

Table 3: Proximate composition of muffins.

Product code	Specific volume(cc/g)	L^*		a^*		b^*	
		Crust	Crumb	Crust	Crumb	Crust	Crumb
A	2.48 ± 0.01^b	14.31 ± 0.175^d	18.36 ± 0.15^c	4.9 ± 0.020^a	4.57 ± 0.064^a	6.32 ± 0.07^d	8.32 ± 0.02^d
B	2.53 ± 0.02^c	11.41 ± 0.203^b	16.62 ± 0.10^b	4.69 ± 0.36^b	4.8 ± 0.011^b	5.54 ± 0.08^c	7.4 ± 0.030^c
C	2.56 ± 0.01^c	10.42 ± 0.211^c	14.16 ± 0.45^a	4.24 ± 0.040^c	4.84 ± 0.010^c	4.0 ± 0.015^b	7.08 ± 0.03^b
D	2.58 ± 0.01^a	9.55 ± 0.87^a	14.04 ± 0.020^a	5.1 ± 0.030^d	5.45 ± 0.010^d	3.7 ± 0.051^a	6.92 ± 0.04^a

Note: *Expressed on dry matter basis, Values are expressed as Mean ± standard deviation (n = 3) Means with different superscripts in a column differ significantly at p< 0.05 by Tukey's test. L*, Lightness; a*, redness/greenness; b*, yellowness/blueness.

Table 4: Specific volume and color analysis of muffins.

Properties	A	B	C	D
Hardness(N)	16.78 ± 0.288^d	22.31 ± 0.288^c	27.54 ± 0.10^b	31.02 ± 0.26^a
Cohesiveness(N)	2.61 ± 0.020^a	3.87 ± 0.36^b	6.97 ± 0.040^c	15.42 ± 030^d
Gumminess(N)	2.51 ± 0.064^a	5.13 ± 0.011^b	8.53 ± 0.010^c	11.78 ± 0.010^d
Springiness(mm)	0.800 ± 0.040^d	0.77 ± 0.072^c	0.76 ± 0.321^b	0.72 ± 0.100^a
Chewiness(N/nm)	6.41 ± 88^d	5.76 ± 0.264^c	3.95 ± 0.0011^b	2.01 ± 0.46^a
Total phenol content (mg/100g)	11.86 ± 0.040^d	9.93 ± 0.072^c	8.83 ± 0.321^b	7.80 ± 0.100^a
%Antioxidant activity	56.10 ± 0.88^d	64.35 ± 0.372^c	75.4 ± 0.200^b	96.1 ± 0.320^a
% Metal chelating activity	23.4 ± 0.260^d	33.3 ± 0.264^c	52.22 ± 0.166^b	58.36 ± 0.46^a
Non enzymatic browning index	0.0078 ± 0.00013^d	0.0130 ± 0.00021^c	0.019 ± 0.0011^b	0.0248 ± 0.00029^a

Note: *Expressed on dry matter basis Values are expressed as Mean ± standard deviation (n = 3) Means with different superscripts in a column differ significantly at p< 0.05 by Tukey's test.

Table 5: Texture and bioactive properties of muffins.

Gumminess of muffins was increased reaching from 2.5N to 11.78N. Lim (2013) [30] reported similar results for bread prepared with young corn powder. Cohesiveness values for muffins ranged from 2.61 (Formulation A) to 15.42N (Formulation D). Chewiness is the product of springiness, hardness and cohesiveness. Addition of baby corn flour decreased this parameter **Table 5** showing that product prepared from baby corn flour was easy to chew. Jauharah et al. (2014) [25] also observed that addition of baby corn powder reduces chewiness of muffins. Springiness is related with elasticity and is the height at which the food is recovered. With addition of baby corn springiness value reduced from 0.80 to 0.74 mm. The results for springiness of muffins found to be in accordance with the results reported by Jauharah et al. (2014) [25].

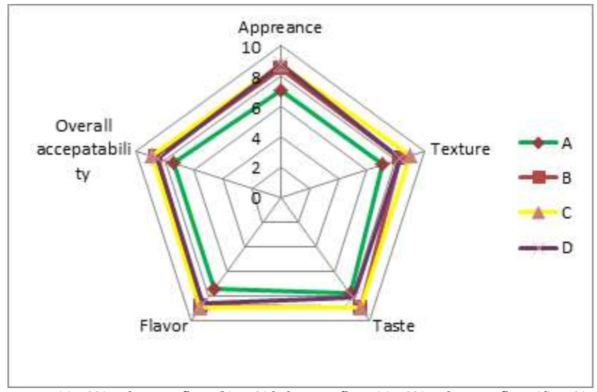
This study documented reduction in total phenol content after baking due to hydrophilic nature of phenolic compounds and their leaching during baking (Table 5). Further, similar trend was observed by Sharma and Gujral (2011) [20] suggesting that the phenolic compounds were lost during thermal processing. A decrease of 11.86 to 7.8% proposes that baby corn antioxidants are more susceptible to changes during baking. This decrease was because of change in chemical structure of the phenolic compounds, as polymerization happens which reduces oxidation and extractability. NEBI of muffins increased with increased concentration of baby corn flour (Table 5). The increased levels associated with maillard browning which increases browning index of muffins. Ramirez-Jimenez et al. (2000) [33] also reported that baking of bread at 180-200°C increases its browning index. Further, in addition to maillard browning, caramelization of sugars also increases browning index [20]. The NEBI of the muffins increased with increased proportion of baby corn flour (0.0078 to 0.0248) because of dilution of proteins and sugars of baby corn flour.

The inhibition of the percentage of DPPH radicals increased with increased proportion of baby corn flour. BCF demonstrated more antioxidant activity than other flours because of its greater polyphenols content. The antioxidant activity of muffins prepared with A, B, C and D formulations was recorded 56.1, 64.3, 75.4 and 96.1%, respectively. Singh and Kaur (2020) [6] reported similar results for antioxidant activity of baby corn soup mix with expanding level of baby corn powder. Increased antioxidant activity of barley cookies with processing like baking and microwave roasting had been reported earlier [20].

Increased concentration of baby corn flour in muffins resulted in increased metal chelating activity. Filipcev et al. (2011) [34] also showed increase in metal chelating activity of cookies made with rye and Buck wheat flour. An increase of 28.3 (Formulation A) to 58.38 % (Formulation D) was seen in blends. Sharma and Gujral (2011) [20] reported that thermal processing produces maillard brown pigments, which exhibited higher chelating activity than their precursors.

Sensory quality of muffins

The panelists evaluated the muffins for their flavor, taste, color and appearance, based on 9-point hedonic scale **(Figure 1)**. Data shows better scores for formulation C (20% baby corn flour) while formulation A (10% baby corn flour) had the lowest sensorial scores. Overall acceptance of muffins with formulation C had the highest hedonic scores among all the formulations. This finding was in concordance with other studies, where scientists reported that sensory acceptance of baby corn products i.e. several Indian snacks, pickles and savories were higher as compared to control products [35]. In contradiction, muffins and biscuits prepared with 10% young corn powder received better score as compared to control [25]. Thus, formulation with 20% baby corn powder was selected best for preparation of gluten free muffins.



Note: (a) 10% Baby corn flour (b) 15% baby corn flour (c) 20% Baby corn flour (d) 25% Baby corn *Sensory score out of 9.0 (n = 20).

Figure 1: Sensory evaluation of gluten free muffins.

Conclusion

The preparation of baby corn flour may be an alternative to the use of this food crop for production of gluten free products. The present study concluded that baby corn flour is suitable for preparation of gluten free muffins with acceptable sensory attributes and improved nutritional profile. Consequently, advancement and use of such functional foods won't just improve the dietary status of the population, yet in addition helps those experiencing celiac infection. The finding of this study may also help to create innovation to differentiate the utilization of baby corn flour by the food processing enterprises, exceptionally baking businesses. More examinations should be led to search the chances of utilizing baby corn flour as an ingredient in other food items to expand its utilization of such value-added food ingredients.

Author Contributions

AS- Conceived, carried out the experiments and wrote the MS, KK supervised the work and edited the manuscript.

Acknowledgements

Laboratory facilities provided by Head, Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, India to execute the present work are duly acknowledged. Authors are also thankful to Mr. Aman Thapar, Plant Head, Field Fresh Foods Pvt. Ltd. Ladhowal for providing raw material to conduct the studies.

References

1. Hosseini SM, Soltanizadeh N, Mirmoghtadaee P, Banavand P, Mirmoghtadaie L, et al. Gluten-free products in celiac disease: Nutritional and technological challenges and solutions (2018) J Res Med Sci 23: 109. https://doi.org/10.4103/jrms.JRMS_666_18
2. Vidaurre-Ruiz J, Matheus-Diaz S, Salas-Valerio F, Schoenlechner R and Repo-Carrasco-Valencia R. Influence of tara gum and xanthan gum on rheological and textural properties of starch-based gluten-free dough and bread (2019) Eur Food Res Technol 245: 1347-1355. https://doi.org/10.1007/s00217-019-03253-9
3. Jnawali P, Kumar V and Tanwar B. Celiac disease: Overview and considerations for development gluten-free foods (2016) Food Sci Human Wellness 5: 169-176. https://doi.org/10.1016/j.fshw.2016.09.003

4. Demirkesen I and Ozkaya B. Recent strategies for tackling the problems in gluten-free diet and products (2020) Crit Rev Food Sci Nutr 28: 1-27. https://doi.org/10.1080/10408398.2020.1823814
5. Araujo ED, Francielle DMS, Silva FCD and Ildeu DOJ. Growth and yield of baby corn as influenced by nitrogen top dressing (2017) African J Agri Res 12: 963-969. https://doi.org/10.5897/AJAR2016.11931
6. Singh V and Kaur K. Development, formulation and shelf life evaluation of baby corn soup mix from industrial by-products (2020) J Food Sci Technol 57: 1917-1925. https://doi.org/10.1007/s13197-019-04227-1
7. Garcia-Valle, Daniel E, Luis A. Bello-Perez, Pamela C. Flores-Silva, Tovar J. Extruded Unripe Plantain Flour as an Indigestible Carbohydrate-Rich Ingredient (2019) Front Nutr 13: 415-422. https://doi.org/10.3389/fnut.2019.00002
8. Anajekwu EO, Dixon BM, Akinoso R, Awoyale W and Alamu EO. Physicochemical Properties and Total Carotenoid Content of High-Quality Unripe Plantain Flour from Varieties of Hybrid Plantain Cultivars (2020) J Chem 20: 311-319. https://doi.org/10.1155/2020/5960346
9. Taghdir M, Mazloomi SM, Honar N and Sepandi M. Effect of soy flour on nutritional, physicochemical, and sensory characteristics of gluten-free bread (2016) J Food Sci Nutr 5: 245-249. https://doi.org/10.1002/fsn3.411
10. Saha A and Mandal S. Nutritional Benefit of Soybean and Its Advancement in Research (2019) J Food Sci Technol 5: 6-16. https://doi.org/10.18052/www.scipress.com/SFP.5.6
11. Fried HG, Narayanan S and Fallen B. Characterization of a soybean (Glycine max L. Merr.) germ plasm collection for root traits (2018) Plosone 13: 1723. https://doi.org/10.1371/journal.pone.0200463.g002
12. Gupta SM, Arora S, Mirza N, Pande A, Lata C, et al. Finger Millet A "Certain" Crop for an "Uncertain" Future and a Solution to Food Insecurity and Hidden Hunger under Stressful Environments (2017) Front Plant Sci 8: 643. https://doi.org/10.3389/fpls.2017.00643
13. Ovando-Martinez M, Sayago-Ayerdi S, Agama-Acevedo E, Goni I and Bello-Perez LA. Unripe banana flour as an ingredient to in-crease the undigestible carbohydrates of pasta (2009) Food Chem 113: 121-126. https://doi.org/10.1016/j.foodchem.2008.07.035
14. Official Methods of Analysis. Association of Official Analytical Chemists (17th Edn) (2012) Washington, USA.
15. Singh A, Sharma S and Singh B. Influence of grain activation conditions on functional characteristics of brown rice flour (2017) Food Sci Technol Int 23: 500-512. https://doi.org/10.1177/1082013217704327
16. Zhang W, Yang Q, Xia M, Bai W, Wang P, et al. Effects of nitrogen level on the physicochemical properties of Tartary buckwheat *Fagopyrum tataricum* (L.) Gaertn.) Starch (2019) Int J bio macromols 129: 799-808. https://doi.org/10.1016/j.ijbiomac.2019.02.018
17. Jyotsna R, Soumya C, Indrani D and Rao GV. Effect of replacement of wheat flour with finger millet flour (*Eleusine corcana*) on the batter microscopy, rheology and quality characteristics of muffins (2011) J Texture Stud 42: 478-489. https://doi.org/10.1111/j.1745-4603.2011.00309.x
18. Approved methods of American Association of Cereal Chemists (10th Ed) (2000) The Association St. Paul, Minnesota.
19. Kaur R, Kaur K, Wagh RV, Kaur A and Sachdev A. Red bell pepper (*Capsicum annuum* L.): Optimization of drying conditions and preparation of functional bread (2020) J Food Sci 85: 2340-2349. https://doi.org/10.1111/1750-3841.15317
20. Sharma P and Gujral HS. Effect of sand roasting and microwave cooking on antioxidant activity of barley (2011) Food Res Int 44: 235-240. https://doi.org/10.1016/j.foodres.2010.10.03
21. Chis MS, Paucean A, Man SM, Muresan V, Socaci SA, et al. Textural and Sensory Features Changes of Gluten Free Muffins Based on Rice Sourdough Fermented with Lactobacillus spicheri DSM 15429 (2020) Foods 9: 363. https://doi.org/10.3390/foods9030363
22. Cardello AV. Hedonic scaling: assumptions, contexts and frames of reference (2017) Curr Opin Food Sci 15: 14-21. https://doi.org/10.1016/j.cofs.2017.05.002
23. Kaur N, Kaur K and Aggarwal P. Parameter optimization andnutritional evaluation of naturally fermented baby corn pickle (2018) Agric Res J 55: 548-553. https://doi.org/10.5958/2395-146X.2018.00096.0
24. El Wakeel MA. Preparation of Dried Vegetarian Soup Supplemented with Some Legumes (2007) scientific research 5.
25. Jauharah AMJ, Ishak WRW and Robert SD. Physicochemical and Sensorial Evaluation of Biscuit and Muffin Incorporated with Young Corn Powder (2014) Sains Malaysiana 43: 45-52.
26. Iwe MO, Onyeukwu U and Agiriga AN. Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour (2016) Cogent Food Agric 2: 1-10. https://doi.org/10.1080/23311932.2016.1142409
27. Danbaba N, Anounye JC, Gana AS, Abo ME, Ukwungwu MN, et al. Physical and pasting properties of 'ofada' rice (*Oryza sativa* L.) varieties (2012) Niger Food J 30: 18-25. https://doi.org/10.1016/S0189-7241(15)30009-6
28. Hooda S and Kawatra A. Nutritional evaluation of baby corn (*zea mays*) (2013) Nutr Food Sci 43: 68-73. https://doi.org/10.1108/00346651311295932
29. Zaker Md A and Genitha TR. Effects of Defatted Soy Flour Incorporation on Physical, Sensorial and Nutritional Properties of Biscuits (2012) J Food Process Technol 3: 4. https://doi.org/10.4172/2157-7110.1000149
30. Lim JY and Ishak WRW. The ability of *Zea mays* ears (Young Corn) powder in enhancing nutritional composition and changing textural properties and sensory acceptability of yeast bread (2013) Int Food Res J 20: 799-804.
31. Singh JP, Kaur A, Shevkani K and Singh N. Influence of jambolan (Syzygium cumini) and xanthan gum incorporation on the physicochemical, antioxidant and sensory properties of gluten free eggless rice muffins (2015) Int Food Sci Technol 50: 1190-1197. https://doi.org/10.1111/ijfs.12764
32. Laguna L, Salvador A, Sanz T and Fiszman SM. Performance of a resistant starch rich ingredient in the baking and eating quality of short-dough biscuits (2011) J Food Sci Technol 44: 737-746. https://doi.org/10.1016/j.lwt.2010.05.034
33. Ramirez JA, Guerra HE and Garcia VB. Browning indicators in bread (2000) J Agric Food Chem 48: 4176-4181. https://doi.org/10.1021/jf9907687
34. Filipcev B, Smurina O, Sakac M, Sedej I, Jovanov P, et al. Feasibility of use of buckwheat flour as an ingredient in ginger nut biscuit formulation (2011) Food Chem 125: 164-170. https://doi.org/10.1016/j.foodchem.2010.08.055
35. Anitha G and Rajyalakshmi P. Baby corn (*Zea mays L*): Physico-chemical characteristics and use in product development (2005) J Food Sci Tech 42: 234-238.