Original Research Article

Utilization of Millet, Cassava and Chickpea to Prepare High Nutrient Different Products for Celiac Patients

Abstract

This research aims to produce crackers for celiac disease with important nutritional value and sensory characteristics using cassava flour, millet flour, and chickpea flour. The materials used in this investigation were cassava, millet and chickpea flour in addition to additional components to making crackers. The study revealed that most of all the parameters studied were significant in producing high quality crackers. The obtained findings showed that the chemical composition of crude protein, fat, and crude fiber in cassava, millet and chickpea flour were a higher than those of wheat flour. There was a significant ($p < 0.05$) increase in mineral content (calcium, potassium, Iron, zinc, and magnesium) compared with the control sample. The chemical composition of the raw materials and crackers formulas was analyzed, and the results showed that all formulas made with cassava, chickpea and millet had higher crude protein, fat, ash, and fiber contents than formulas made with wheat flour alone. The crackers blend (1) made from (50% cassava, 40% chickpea and 10% millet flour) has higher total mineral content than crackers other. The sensory scores showed that the blend (3) sample made from 50% cassava, 35% chickpea and 15% millet had the highest scores among all the samples in terms of flavor, taste, texture, and color, and was also the most preferred by the panelists based on the overall acceptability. **Conclusion:** The results indicated that the formulation of chickpea, cassava, and millet crackers with acceptable color and sensory properties which would be a gluten-free, nutrient-dense alternative to traditional crackers.

Keywords: crackers, celiac disease, gluten-free, cassava, millet, chickpea.

1. Introduction

The widespread and growing trend of snacking across all age groups has continued to provide ready-to-eat snack products with a competitive advantage in the global food market. The increasing popularity of snack foods can be explained by several factors: their cost-effective production, ease of use, extended storage life, and capacity to deliver essential nutrients **[1].** Another significant factor is the evolving lifestyle of consumers. Nevertheless, additional studies are necessary to address the growing demand for more nutritious and functional snack options, as most current snack products are considered unhealthy, containing high levels of fat, sugar, and salt, while offering minimal nutritional value.

Celiac disease, also referred to as gluten intolerance, is a condition that impacts individuals with a genetic predisposition to react adversely to gluten. **[2]**Gluten is described as a naturally occurring protein found in wheat and rye, with similar proteins existing in oats and barley. Consequently, all food products derived from these grains contain gluten. This persistent condition impacts approximately one out of every 200 individuals globally **[3]**. When a person with celiac disease consumes gluten-containing food, their body reacts to it like an allergy. The villi flatten as a result of inflammation of the intestinal lining, decreasing the surface area of the gut and impairing its ability to absorb nutrients **[4**. Malnutrition may then result from weight loss and wasting **[2]**. Severe symptoms have been documented, including persistent stomach pain and bloating, diarrhea, constipation, weight loss, and even blistering rash **[4]**. Another type of gluten intolerance that affects the skin is called dermatitis herpetiformis (DH), and it causes itchy, watery sores **[3].**

As of right now, there is no medication for treating gluten intolerance; the best course of action is to follow a gluten-free diet **[4] [2] [5]**. Micronutrient deficits (e.g., thiamine, riboflavin, niacin, iron, selenium, chromium, magnesium, folacin, phosphorus and molybdenum) can occur in people following any kind of avoidance diet **[6]**.

As a snack food, crackers presently hold a sizable market share and provide promising opportunities for the development of new products, especially in the functional food sector **[7].**

Snack foods are an essential component of a diet and have been heavily marketed for a long time. Crackers are a widely consumed snack item with a significant demand from customers **[8] [9] .**

Manihot esculenta Crantz, sometimes known as cassava, is thought to be a significant staple crop that offers a range of phytoconstituents and a potential beneficial food source.

Its starchy tubers give about 500 million people a substantial source of energy. It's considered one of the best sources of carbohydrates among staple crops. Its availability and physicochemical characteristics have made it an alluring food ingredient. There is potential for cassava flour and starch to be useful substitutes for wheat, maize, and rice crops.

The benefits included serving as an essential component of human diets, an ingredient in animal feed, a raw material for food processing, edible coatings, alcoholic beverages made locally, and ethanol production. The bioactive ingredients in cassava may be used to make both conventional and contemporary food applications as well as a variety of pharmaceutical medications **[10].**The cassava is a member of the family Euphorbiaceae, which includes over 7200 species and is mostly composed of secretory cells known as lacticifers.

These are able to yield the "latex," or milky liquid, that sets this family of plants apart. Asia, Africa, and Latin America are among the tropical regions where cassava is a common meal due to its starchy root.

The Food and Agriculture Organization (United Nations) states that cassava (*Manihot esculenta Crantz*) is an essential part of nearly half a billion people's diets **[11]**.

Cassava has been used as a raw resource for industry, alternative fuel production, animal feed, and human food production. The majority of cassava in Nigeria is transformed into several foods for human use. Cassava roots are rich in carbohydrates and have a good nutritional value. Their carbohydrate production is 20% and 40% higher than that of corn and rice, respectively **[12]**.

In many nations in Africa, Asia, Latin America, and the Caribbean, cassava is a staple diet. This crop is very important to culture and society. As a result, cassava is crucial for food security and nutrition, and it generates cash for growers, processors, and traders, all of which significantly reduce poverty **[13].**

Manihot esculenta Crantz, also known as cassava, is one of the most significant tuber crops grown in tropical and subtropical areas and feeds about 800 million people globally **[14].**

In the arid and semi-arid tropical regions of India and Africa, pearl millet (*Pennisetum glaucum*), a cereal that is a member of the Poaceae grass family, is the most often planted species. It produces half of the millet produced worldwide and is able to withstand extreme weather **[15] [16].** It is widely consumed in many African nations as thick and thin porridges (ogi), steam-cooked goods (couscous), and as a component of beer made in breweries. Due to its high amounts of minerals like phosphorus (296 mg/100 g) and zinc (3.1 mg/100 g) as well as its high quality protein (11.6–11.8%), it is more nutritious than many other cereal crops like corn and sorghum **[17].** It has also been demonstrated to have potent antioxidant effects and a high concentration of bioactive ingredients, including ascorbic acid and phenolic compounds **[18]**. Pearl millet is a viable gluten-free substitute for wheat that may help lower the risk of celiac disease and improve the use of locally grown crops. Additionally, compared to its roasted and fermented substitutes, germinated pearl millet flour was observed to have a much higher crude protein content as well as the ability to absorb both water and oil **[15]**, thus germination is a better processing technique for producing premium pearl millet flour that can be utilized in the manufacturing of food. However, to create more nutritious meals that can help fight protein-energy malnutrition (PEM), protein sources like legumes must be added to cereal meals like pearl millet meal because of their comparatively poor nutritional content.

Due to the high concentration of vital nutrients including carbohydrates, B vitamins, minerals, polysaccharides (antioxidants), and dietary fibers that millets contain, they are an extremely significant source of additional nourishment for humans**[19]**. Millets are rich in nutrients; their percentages of carbs, fat, protein, dietary fiber, and minerals are 60–70%, 1.5–5%, 6–19%, 12–20%, and 2-4 percent, respectively**[20]**. With the exception of lysine and threonine, its proteins are rich in essential amino acids. These grains are also excellent providers of phytochemicals and minerals **[21] [22].**

Cicer arietinum L., the scientific name for chickpea, is a member of the Cicereae tribe of the Fabaceae family, more precisely the Papilionaceae subfamily **[23].**

In India, chickpea dominates the rabi pulse crop, making up 50% (13.5 mt) of the total amount of pulses produced there. This economical, nutrient-dense legume is an excellent source of protein, energy, minerals, vitamins, and dietary fiber. Beyond their basic nutritional value, chickpeas contain a wide range of non-nutritive phytochemicals, such as enzyme inhibitors, oligosaccharides, tannins, polyphenols, and flavonoids, which show promise for their ability to lower cholesterol and have anti-inflammatory, antioxidant, anti-diabetic, anti-obesity, and prebiotic properties **[24]**.

Chickpeas are a popular food because of its high nutritional content and use as a high-energy and protein source in human diets **[25]**.

It is well known that chickpeas are an excellent source of vital minerals and that they play a major role in the general upkeep of human existence. It is essential for increasing dietary intake of zinc (Zn) and iron (Fe) in humans. The ranges of iron and zinc contents in chickpea seeds are 44.1-76.7 mg/kg and 36.3-56.2 mg kg^{-1}, respectively **[26] .**

Due to their high protein content, legumes are a popular choice for vegetarians, low-income families, and the impoverished. Chickpeas are also an inexpensive source of protein **[27] .** Protein, carbohydrates, minerals, and many types of other essential nutrients may be obtained from chickpeas. All of the essential amino acids are present in significant concentrations in chickpeas (EAAs) **[28]**.

Chickpea seeds have 2-3 times more protein than cereal grains, ranging from 16.7% to 30.6% for desi cultivars and 12.6% to 29.0% for kabuli cultivars **[29].** The study's goal is to use cassava, millet, and chickpea flour to make crackers with significant nutritional value, color parameters, and sensory attributes for celiac patients.

2. Materials and Methods

2.1 Materials

1. Wheat flour (72% extr) (*Triticum aestivum*) acquired from Tanta City, Egypt's Delta Middle and West Milling Company.

2. **Pearl millet (shendawil) (***Panicum miliane***)** was acquired from Field Crops Dep., Agr. Res. Center, Giza, Egypt.

3.**Chickpeas** (*Cicer arietinum*) **,Cassava flour (***Manihot esculenta Crantz***)** and other The ingredients required for making crackers, for example , oil, sugar(sucrose), baking powder, salt(NaCl) and spices (curcuma , cumin and Paprika (Red pepper))were acquired from the local market, Kafrelsheikh city, Egypt.

4. Solvents and chemicals were bought from EL-Gomhoria Company in Cairo, Egypt.

2.2 Methods

2.2.1 Preparation of chickpea flour

It was deliberate to remove any harmful substances from the chickpea seeds before cleaning them with tap water. Based on that, they were immersed in tap water at room temperature (25±2˚C) for 12 hours **[30]**. Soaked Over a period of eighteen hours, seeds were dried at 45 C. utilizing a German Bra bender Duisburg roller mill that is electric Grind the millet and chickpea seeds to a fine flour and keep them in polythene bags in the fridge (5°C) until used According to the methods outlined by **[31]**.

2.2.2 Crackers Preparation

Table (1) displays the Crackers formula. The dry ingredients—cassava flour, millet flour, and chickpea flour—as well as the salt (sodium chloride), cumin, curcuma, red pepper, and baking powder—apart from sucrose—were combined in the mixing bowl and left for thirty seconds in line with the procedure outlined by **[32].** After 30 seconds of mixing the wet components (oil, sugar, and water), combine all of the ingredients. Cut into a circle after acquiring the dough and letting it rest at room temperature for ten minutes. After that, the crackers were put in an electric oven and baked for 4 minutes at 175 °C. After cooling for 30 minutes, they were placed in plastic bags and kept at room temperature.

Table (1): The formula used for preparing crackers

Components	B1	B2	B3	B4
wheat flour (g)	100	---	---	---
Cassava flour(g)	---	50	50	50
Desi-chickpea flour(g)	---	40	35	30
Millet flour(g)	---	10	15	20
Oil(g)	10	10	10	10
Salt(g)	4	4	4	4
Sucrose (g)	3	3	3	3
Cumin(g)	1	1	1	1
Curcuma(g)	2	2	2	2
Red pepper(g)	0.5	0.5	0.5	0.5
Baking powder(g)	2	2	2	2

B1= 1000 g wheat flour

B2= 50 g Cassava flour+40g Desi-chickpea flour +10g Millet flour

B3= 50g Cassava flour+35g Desi-chickpea flour +15g Millet flour

B4= 50g Cassava flour+30g Desi-chickpea flour +20g Mille flour

2.2.3 Chemical Analysis

Protein, moisture, ash, crude fiber, and ether extract in pearl millet flour, chickpea flour, cassava flour, and crackers were evaluated using**[33] .** Carbohydrates available were computed as a difference.

Available carbohydrates = 100 – (protein + ash + ether extract + crude fiber)

2.2.4 Determination of minerals

Ca, Mg, Mn, K, Fe, Zn, P, and Se mineral concentrations were calculated using the procedures of **[34]**. These minerals were identified using an atomic absorption spectrophotometer (Perkin Elmer, Model 3300, USA).

2.2.5 Determination of Amino Acids Composition

The National Research Center in Cairo, Egypt performed an amino acid analysis of cracker blends made from pearl millet flour, chickpea flour, cassava flour using a

Beckman amino acid analyzer (Model 119CL), using the previously established methodology **[35] .**

2.2.6 Sensory Evaluation of Crackers

Twenty staff members of the Bread and Pastry Department of the Food Technology Research Institute in Egypt assessed the appearance, color, odor, taste, crispiness, and overall acceptability of all the cracker products made from various ratios of cassava, millet flour, and chickpea flour. The panelists were asked to rate each of the above characteristics on a standard hedonic rating scale that ranged from 9 (like extremely) to 1 (dislike extremely), according to **[32].**

2.2.7 Color measurements

The outside color of the crackers was assessed using a handheld Chroma meter using the method outlined by **[36].**The Minolta CR-A70 (Konica Minolta Co., Ltd., Tokyo, Japan) was used to examine the color characteristics of GA-AOE films. The following was how the results were displayed straight from the machine's screen: *a** values demonstrated color transfers from green to red, *b** values showed color shifts from blue to yellow and *L** values showed changes from darkness to lightness.

2.2.8 Statistical Analysis

With the use of the statistical software application SPSS, version 25, data were statistically tested. Each and every value is given as Mean ± SD. A one-way ANOVA and a post-hoc Duncan test were used to assess the statistical significance of the difference in multiple group comparisons.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of raw materials (wheat72%, cassava, chickpea and millet flour).

The table (2) contains the chemical compositions of the used flour that was being investigated. It could be noticed that the crude protein content of the four flour samples ranged from 5% to 24%, with significant differences between the lowest values 5% (cassava flour) and 11.80% (wheat flour extraction72%), and the highest value 24.00%, chickpea flour . The ash of cassava flour was higher than wheat, chickpea and millet flour which show there is a higher quantity of minerals in cassava flour in comparison to wheat, chickpea and millet flour. Ether extract and crude fiber content were higher in chickpea flour. Available Carbohydrate flours range from 59.90% to 85.10%. The highest available carbohydrates content is found in wheat flour, while the lowest carbohydrates level is in chickpea flour. Other nutrient components such as water content, protein, fat, and ash levels can also increase and reduce the amount of carbohydrates. On the other hand, if the levels of other nutrients decrease, the amount of carbohydrates increases. Legume flours can be added to a cassava-based composite flour to increase its protein content because they are often high in carbohydrates and low in protein **[37].**

Table (2): Composition analysis of raw materials (on dry weight basis %)

Composition analysis of raw materials	Materials			
	Wheat flour 72%	Cassava flour	Millet flour	Chickpea flour
Crude protein%	11.80^{c}±0.05	5.00^{d}±0.06	13.50^{b}±0.05	24.00^{a}±0.20
Ether extract%	1.95^{c}±0.05	1.40^{e}±0.07	6.00^{b}±0.06	6.60^{a}±0.09
Ash%	0.55^{d}±0.05	4.90^{a}±0.06	4.00^{b}±0.04	3.50^{c}±00.07
Crude fiber%	0.60^{d}±0.05	4.70^{c}±0.02	5.20^{b}±0.05	6.00^{a}±0.03
*Available carbohydrates%	85.10^{a}±0.05	84.00^{b}± 0.40	71.30^{c}±0.50	59.90^{d}±0.20
Caloric value (kcal/100g)	415.04^{a}±0.05	377.64^{d}±0.30	402.28^{c}±0.40	404.05^{b}±0.20

-Each mean value is followed by ± SE (standard division)

-Means in the same column with different letters are significantly different (p≤ 0.05).

3.2 Minerals content of used wheat72%, cassava, chickpea and millet flour

Table (3) displays the mineral composition of wheat, chickpea, and millet flours. The findings indicate that chickpea flour contained higher levels of P, K, Fe, and Mn (300, 1250.30, 7.80, and 6.16 mg/100g, respectively). In contrast, cassava flour exhibited the highest concentrations of Ca, Na, and Mg (270, 135.38, and 180 mg/100g, respectively).

Table (3) : Minerals content of used wheat72%, cassava, chickpea and millet flour

Minerals (m g /100 g)	Wheat flour 72% (mg /100 g)	Cassava flour (mg /100 g)	Millet flour (mg /100 g)	Chickpea flour (mg/100 g)
K	155.40±2.50	455^{c}±2.50	310.50^{b}±2.5	1250.30± 3.50
Ca	19.20±2.50	270^{a}±4.00	18.00^{b}±0.55	185.30±0.70
P	135.50±2.50	240^{b}±1.40	145^{c}±0.65	300±0.80
Na	4.95±2.50	135.38^{a}±5.50	4.60±1.00	28.30±0.09
Mg	129.80±2.50	180^{b}±0.90	150^{c}±0.95	165.90±2.0b
Fe	2.01±2.50	3.60^{c}±0.02	5.80^{b}±0.03	7.80±0.04
Mn	0.95±2.50	5.80^{a}±0.05	2.80^{c}±0.01	6.16^{b}±0.03
Zn	4.90±2.50	1.93^{c}±0.01	3.50^{b}±0.01	4.10^{a}±0.02
Vitamins (mg /100g)				
Vitamin C	nd	13.80^{c}±0.04	0.90^{a}±0.01	2.70^{b}±0.01
B-carotene	2.50	1.50^{c}±0.01	1.14^{a}±0.03	6.50^{b}±0.02

-Each mean value is followed by ± SE (standard division)

-Means in the same column with different letters are significantly different (p≤ 0.05).

3.3 Proximate Composition of Crackers Made from cassava, chickpea and millet flour blends:

Table (4) displays the proximate composition analysis of the cracker samples. Significant variations (p ≤ 0.05) were observed in the protein content across samples, ranging from 9.83% to 11.73%. The highest protein content (11.73%) was found in sample blend (2), consisting of 50% Cassava flour, 40% desi-chickpea flour, and 10% Millet flour. Conversely, the lowest protein content (9.83%) was detected in sample blend (1), the control sample made entirely of wheat flour. Sample blend (4), composed of 50% cassava flour, 30% desi-chickpea flour, and 20% Millet flour, had the second-lowest protein content. These findings indicate that increasing the proportion of millet flour in the blends resulted in a decrease in protein content. Notably, even the blended samples exhibited higher protein content than the control sample made solely from wheat flour. According to **[37]** the protein content of a cassava-based composite flour can be elevated through the incorporation of legume flours since they are usually carbohydrate dense and very low in protein.). In respect of moisture content, it could be noted that control had the highest moisture content (6.06%). Blend (2) had the high moisture content (5.35%) and significantly increased differences between crackers made from different blend (2-4) and blend (1) control. The fat content of the samples ranged from 6.06 –3.09 %. Blending cassava, chickpea and millet flour no significant differences between the ash content of crackers to 3.54–3.56 and 3.58% respectively in blends (2-4), also fiber content of cracker to 4.39-4.33 and 4.35 respectively in blends (2-4). Blending with different proportions of cassava, chickpea and millet flour significantly increased the protein, ash, fiber and fat content of crackers in comparison to control of blend(1) ,while blend(1) control made with 100 % wheat flour high carbohydrates content and calories in comparison to other blends made with cassava, chickpea and millet flour .

Table (4): Chemical composition of wheat, cassava, chickpea and millet flour blends (g /100 g).

Blends	Chemical composition of wheat, cassava, chickpea and millet flour blends (g /100 g)						
	Moisture content	Crude protein	Crude ether extract	Crude fibre	Ash	Available carbohydrates	Caloric value (kcal/100 g)
Blend (1)	6.06^{a} ± 0. 10	9.83^{e} ±0.07	9.95^{b} ± 0.09	0.50^{b} ± 0.02	0.46^{b} ±0.01	79.26^{a} ± 0.05	455.81^{a} ± 0.30
Blend (2)	5.35^{b} ± 0.05	11.73^{a} ±0.02	11.61^{a} ±0.10	4.39^{a} ± 0.01	3.54^{a} ±0.022	68.73^{d} ± 0.01	435.53^{b} ± 0.20
Blend (3)	4.33^{c} ± 0.06	10.77^{b} ±0.01	11.58^{a} ±0.14	4.35^{a} ± 0.02	3.56^{a} ±0.020	69.74^{c} ± 0.02	435.47^{b} ± 0.30

Blend (4)	3.09[d] ± 0.13	10.33[c] ±0.03	11.56[a] ±0.12	4.33[a] ± 0.02	3.58[a] ±0.01	70.20[b] ± 0.03	435.37[b] ± 0.40

-Means in the same column with different letters are significantly different (p≤ 0.05).

-Each mean value is followed by ± SE (standard division).

3.4 Mineral Contents of the Crackers Samples from cassava, chickpea and millet flour blends

Table (5) displays the mineral composition of cracker samples containing cassava, chickpea, and millet. These samples exhibited elevated levels of minerals (calcium, potassium, iron, zinc, and magnesium) in comparison to the control sample. Among the blends, crackers blend (1), consisting of 50% cassava, 40% chickpea, and 10% millet flour, demonstrated the highest total mineral content. This was followed by blend (2) (50% cassava, 35% chickpea, 15% millet flour) and blend (3) (50% cassava, 30% chickpea, 20% millet flour). The iron content across the samples ranged from 4.41 to 4.58%, with no significant ($p < 0.05$) variation observed among the blended samples. Iron, a crucial trace element in human nutrition, plays a vital role in preventing anemia and related health issues. Its deficiency poses a significant global public health challenge **[38].**

Table (5): Mineral Contents of the Crackers Samples from cassava, chickpea and millet flour blends (mg /100 g)

Minerals (m g /100 g)	B2	B3	B4
K	632.22[a]±1.50	593.08[b]±1.30	553.909[c]±1.10
Ca	175.77[a]±0.50	168.8[b]±0.30	161.78[c]±0.20
P	212.08[a]±0.20	205.63[b]±0.30	199.17[c]±0.35
Na	66.23[a]±0.12	65.25[b]±0.10	64.25[c]±0.14
Mg	156.40[a]±0.04	155.60[b]±0.08	154.8[c]±0.05
Fe	4.58[a]±0.12	4.50[a]±0.10	4.41[a]±0.14
Mn	3.56[a]±0.10	3.49[a]±0.15	3.42[a]±0.20
Zn	2.47[a]±0.11	2.44[a]±0.09	2.41[a]±0.15

-Means in the same column with different letters are significantly different (p≤ 0.05).

-Each mean value is followed by ± SE (standard division).

3.5 Amino acids Contents of the Crackers Samples from cassava, chickpea and millet flour blends

Table (6) displays the amino acid composition of the produced gluten-free crackers, including both essential amino acids (such as lysine, leucine, phenylalanine, threonine, isoleucine, valine, methionine, tyrosine, and cysteine) and non-essential amino acids (like glutamic, aspartic, proline, arginine, glycine, alanine, serine, and histidine). The analysis reveals that crackers made from blend2, consisting of 50% cassava, 40% chickpea, and 10% millet, exhibited higher percentages of certain amino acids. Specifically, these crackers contained elevated levels of lysine (5.70%), isoleucine (5.03%), phenylalanine (6.89%), tyrosine (1.81%), cysteine, glycine (4.50%), and arginine (8.3%). These findings align with the research conducted by **[39].**

Furthermore, crackers (blend4) composed of 50% cassava, 30% chickpea, and 20% millet exhibited a higher proportion of total essential amino acids (44.76%). In contrast, crackers (blend2) made with 50% cassava, 40% chickpea, and 10% millet contained a greater percentage of total non-essential amino acids (54.31%).

Table (6): Amino acids Contents of the Crackers Samples from cassava, chickpea and millet flour blends (g. amino acid /100g protein)

Amino acids	B1	B2	B3	B4	FAO/WHO/UNU (1985) pattern
Lysine	3.65	5.70	5.51	5.32	5.80
Isoleucine	4.70	5.03	4.98	4.93	2.80
Leucine	5.30	8.56	8.75	8.95	6.60
Phenylalanine	5.60	6.89	6.87	6.85	6.30
Tyrosine	1.70	1.81	1.76	1.71	
Histidine	4.10	2.79	2.74	2.70	1.90
Valine	4.50	5.88	6.02	6.18	3.5
Threonine	2.30	4.19	4.22	4.25	3.40

Methionine	1.50	2.03	2.10	2.18	2.20
Tryptophan	3.50	0.77	0.83	0.89	1.00
Cysteine	---	0.86	0.85	0.80	
Total (EAA)	**36.89**	**44.51**	**44.63**	**44.76**	
Aspartic acid	7. 50	10.11	10.01	9.91	
Glutamic acid	32.00	16.03	15.97	15.91	
Serine	6.20	5.11	5.05	4.99	
Proline	6.90	4.20	4.26	4.30	
Glycine	3.40	4.50	2.46	4.41	
Alanine	3.80	6.06	6.33	6.60	
Arginine	2.60	8.3	7.99	7.65	
Total (NEAA)	**62.4**	**54.31**	**52.07**	**53.77**	
C-PER	**1.41**	**3.02**	**3.11**	**3.20**	
BV	**64.74**	**81.72**	**82.62**	**83.60**	

3.6 Sensory Properties of Cracker Made from Blends of Cassava, chickpea and millet Flour.

The results indicated that mixtures (2, 3, and 4) surpassed the control blend (1), which was composed entirely of wheat flour, in all characteristic values except for color. The control blend exhibited a higher color value compared to the other mixtures. Among the blends, mixture (3), consisting of 50% cassava, 35% chickpea, and 15% millet, received the highest ratings for color, taste, crispiness, and overall acceptability when compared to the other combinations. Additionally, blend (4), made up of 50% cassava, 30% chickpea, and 20% millet, garnered the highest evaluations for odor and crispness in comparison to the other mixtures.

Table (7): Sensory Properties of Cracker

Blends	Appearance	Color	Odor	Taste	Crispiness	Overall acceptability

	(9)	(9)	(9)	(9)	(9)	(9)
Blend (1)	$7.0^{d}\pm0.15$	$8.50^{a}\pm0.10$	$8.0^{c}\pm0.14$	$6.5^{d}\pm0.20$	$6.5^{c}\pm0.20$	$6.5^{c}\pm0.15$
Blend (2)	$8.5^{a}\pm0.10$	$8.0^{b}\pm0.14$	$8.30^{b}\pm0.10$	$8.5^{b}\pm0.09$	$8.5^{b}\pm0.10$	$8.7^{b}\pm0.08$
Blend (3)	$8.0^{b}\pm0.20$	$8.0^{b}\pm0.12$	$8.80^{a}\pm0.02$	$8.90^{a}\pm0.05$	$8.85^{a}\pm0.09$	$8.9^{a}\pm0.09$
Blend (4)	$7.5^{c}\pm0.13$	$7.5^{c}\pm0.10$	$9.90^{a}\pm0.09$	$8.0^{c}\pm0.10$	$8.85^{a}\pm0.08$	$8.0^{a}\pm0.05$

-Means in the same column with different letters are significantly different (p≤ 0.05).

-Each mean value is followed by ± SE (standard division).

3.7 Color characteristics of cracker

The visual appeal and consumer acceptance of a product are significantly influenced by its color. Table (8) illustrates the color characteristics of crackers made from various flour blends, including those composed entirely of wheat flour (blend 1) and others incorporating cassava, chickpea, and millet flours. The development of color in crackers is attributed to Maillard reactions, a form of non-enzymatic browning that occurs between amino acids and reducing sugars **[40].** The incorporation of cassava, chickpea, and millet into crackers resulted in a statistically significant (P ≤ 0.05) reduction in lightness compared to the control sample (56.70). The L* values decreased to 53.30, 52.63, and 51.12, respectively. This reduction in lightness can be attributed to the higher protein content found in chickpea and millet flour. Previous research has indicated an inverse relationship between protein content and L* value **[41].**The alteration in baked crackers' hue may also be attributed to the oxidation of higher polyphenolic compounds found in chickpea and millet, resulting in a reduction. The incorporation of cassava, chickpea, and millet flour significantly (P ≤ 0.05) elevated the a* values of crackers to 17.39, 16.79, and 17.76 respectively, compared to the control's 13.37. Similarly, this blending significantly (P ≤ 0.05) lowered the b* values to 36.88, 34.34, and 38.53 respectively, in contrast to the control's 40.54. The shifts in a* and b* values were notably apparent as the crackers' color enhanced to a golden brown with increasing chickpea flour content. This work confirms the great importance of applied science in bakery products [42-58].

Table (8): Color characteristics of cracker

Blends	*L**	*a**	*b**	c	h
B1	56.70^{a} ±0.01	13.37^{d} ±0.01	40.54^{a} ±0.01	42.69^{a} ±0.01	71.74^{a} ±0.01
B2	53.30^{b} ±0.01	17.39^{b} ±0.01	36.88^{c} ±0.01	40.77^{c} ±0.01	64.76^{c} ±0.01
B3	52.63^{c} ±0.01	16.79^{c} ±0.01	34.34^{d} ±0.01	38.22^{d} ±0.01	63.95^{d} ±0.01
B4	51.12^{d} ±0.01	17.76^{a} ±0.01	38.53^{b} ±0.01	42.43^{b} ±0.01	65.25^{b} ±0.01

-Means in the same column with different letters are significantly different (p≤ 0.05).

-Each mean value is followed by ± SE (standard division).

4- CONCLUSION

The overall findings suggested that the chemical analysis, sensory characteristics, physical attributes, and color parameters of the crackers produced were improved by blending cassava, chickpea and millet flour.

The nutritional content of the crackers formula is increased by adding cassava, chickpea and millet flour. While maintaining the quality of the crackers produced. Organoleptic characteristics revealed that the biscuits enhanced with cassava, chickpea and millet flour were acceptable and differed significantly from the control crackers in terms of appearance, color, crispiness, taste, odor, and Overall acceptability. Still, it could make some high-quality bakery goods that are suitable for people or consumers using cassava, chickpea and millet flour and WF.

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1.

2.

3.

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