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Chemical Composition, Physical and Sensory Properties of Free -Gluten Chips Fortified with Finger Millet Flour

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Abstract

The aim of this investigation prepared gluten- free finger millet chips samples by substituting white rice and yellow corn flour by finger millet flour at levels 0, 10, 15 and 20%. The chemical compositions, nutritional assessment, physical and sensory properties of finger millet chips are studied. The outcomes displayed that as increasing the levels of replacements of finger millet flour, the protein, ash, fat and fiber are progressively rising but moisture and carbohydrates contents are progressively reduced. So, the GDR protein value and GDR energy are decreased. Additionally, minerals content as calcium, magnesium, zinc and iron are progressively increased. Moreover, the results of physical properties of chip samples showed that the diameter are progressively reduced, while, the thickness are raised. Thus, spread ratio is reduced by rising levels of finger millet flour. Similarly, texture properties as hardness and factorability are gradually increased as increasing levels of finger millet flour. Correspondingly, the results of color of chip samples showed that the (b*) yellowness and (L*) lightness values are decreased, but the redness (a*) value is increased as rising levels of finger millet flour. Also, the result showed that water activity is decreased as increasing levels of finger millet flour. Likewise, the outcome of sensory properties indicated that all chips' samples are acceptable. Moreover, the chips contain 15% finger millet flour has the greatest scores of sensory compared to other chips samples. Commonly, replacing finger millet flour with yellow corn or rice flour can progress the nutritional value, healthy benefit, physical and sensory properties of free gluten chips.

Keywords: Gluten free; corn; rice; finger millet; chips.

Introduction

Celiac disease is a medical problem founded by gluten digestion in susceptive subjects. When gluten is ingested, it becomes an immunogenic antigen that harming the small bowel, triggering a serological reaction **[1].** The only way to treatment the celiac patient's diet must be gluten-free [**2].** It is hard to find components that can substitute gluten to improve accepted sensory properties of gluten-free products. Furthermore, the nutritional values of gluten-free goods have to be judged by patients of celiac. They consume a lot of simple carbs and saturated fats, yet they are deficient in some elements like vitamins, minerals, and dietary fiber [**3-4].** In current years, the market of free gluten goods has grown considerably, and the consumers of gluten-free haven't any choices. Additionally, occasions exist for the use of gluten-free grains like corn, buckwheat, chickpea, Starch from arrowroot that can used in produce gluten-free goods **[5].**

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Chips are the greatest consumed bakery goods due to their, nutritional quality, nature, diverse availability and affordability. Various nutrient-dense ingredients can be assimilated into bakery products to improve nutritional value **[6]**. Chips are thought to be high in energy; however, they frequently lack some vital elements. An opportunity to address these products while preserving product quality and customer happiness is presented by the incorporation of legumes **[7-8]**. Chips consumption is influenced by cost, taste preferences, long shelf life, and versatility, **[9]** The prolonged due to its low moisture content of chips caused increase in period of shelf life it due to decrease the microbial growth, allowing so, the product have the best properties for longer, providing it is accurately stored **[10].**

The main and secondary cereals are consumed semi- processed or either processed with the addition of other food ingredients. Certain grains contain an important quantity of both insoluble and soluble dietary fiber. These cereals offer health-promoting qualities that help prevent or manage certain illnesses, such as heart disease and cancer **[11].**

Maize (*Zea mays*) is one of the oldest, healthiest, and most well-known cereal crops; it is used extensively for food and feed [12]. Because of its increasing crop productivity and genetic potential, it is the most widely available gluten-free cereal [13–14]. In addition to being processed into a variety of extruded and baked goods, including cookies, it is commonly consumed as a staple [14]. Maize flour contains nutritional values and many advantageous chemicals as carotenoids, phenolic compounds, vitamin C, and anthocyanins so, it can have medical purposes on general health as anti-oxidant, anti-diabetic, anti-obesity qualities and wellbeing **[15 -12].**

Rice **(***Oryza sativa L***.)** is the third most produced grain in the world and is frequently utilized in the development of gluten-free products because its hypo allergenicity, easy digestibility bland taste and white color **[16].** Supplying roughly half of the world's population with energy. The market for this cereal has grown because to products like rice flour and starch, which are used as ingredients to make a variety of rice-based products **[17].** The rice whole grain is rich in good fats, minerals vitamins and fiber due to its bran layer and complete germ **[18]**. It has predominantly carbohydrates so; it has a high dietary glycemic index **[19].**

Finger millet (*Eleusine coracana*) is a main cereal known such as tamba, in certain low-income regions of the world. The grain is distinguished by color variations (brown, light brown white) **[20].** Millets are high-nutrient, underused, gluten-free grains. Thus, it can be utilized as a substitute grain to make baked goods. **[21]** It upsurges their nutritional value and improve texture and aroma **[22].** The strong nutritional profile of finger millet is well recognized, and it is also a great source of vitamin B complex (riboflavin and thiamine), in addition to essential amino acids (isoleucine, methionine, phenylalanine, leucine, etc.) **[23].** Besides, the pharmacological properties of finger millet are well regarded as anti-tumorigenic, anti-diabetic, anti-atherosclerogenic, antimicrobial and antioxidant **[24]**.

The purposes of the current investigation are assessed the impact of substituting finger millet flour with white rice and yellow corn flour at different levels on chemical composition, nutritional evaluation, physical and sensory properties of gluten- free chips.

2-MATERIALS AND METHODS

1. MATERIALS: -

Yellow corn flour (*Zea mays*) was obtained from AL Mashreq Gardens company, from Dobella**,** Rice flour **(***Oryza sativa L***.)** from company Zam Zam, finger millet seeds *(Eleusine coracana***),** shortening, powder milk, salt and ground sugar were obtained from the area market, Cairo, Egypt. Lecithin **,**sodium bicarbonate, citric acid **,**xanthan gum, and ammonium were obtained from Al Gomhoria pharmaceuticals and chemical company, Cairo, Egypt.

2. METHODS:

Preparation of finger millet flour

Finger millet (*Eleusine Coracana*) seeds are sorted from the impurities, then are washed well with water many times, and at that point the seeds are dried by sun for three days, after that seed are powdered by the home blender (Tornado food processor FP1000SG) and packaged into polyethylene bags and kept at room temperature for using and analysis.

Preparation of finger millet chips

Preparation pressing of gluten-free chips was based on method of [**25]**. The formula of gluten-free chips was shown in Table (1). All dried ingredients were combined in a bowl using a mixer (Tornado ®, Egypt) the sugar and shortening were mixed well until they made good cream. after that the dry ingredient was gradually added to cream in low speed. The dough was uniformly rolled to a thin thickness on a sheeting board (6.0 mm) and shape using a round steel chips cutter (35.0 mm diameter). Pieces of dough were baked on pans at 180o C for 12 -15 min in oven (Electric ®, Fresh) after that the chips samples were let to cool at room temperature (25±2ºC) for 45-60 min and stored on polyethylene pages for analysis.

Table (1). Formula of finger millet chips.

Materials	Control Chips 0% FM	Chips 10% FM	Chips 15% FM	Chips 20% FM
Corn flour	50	45	42.5	40
Rice flour	50	45	42.5	40
Finger millet flour	-	10	15	20
Sugar	20	20	20	20
shortening	20	20	20	20
Milk powder	10	10	10	10
Sodium bicarbonate	1	1	1	1
Salt	0.5	0.5	0.5	0.5
Lecithin	0.5	0.5	0.5	0.5
Xanthan	1	1	1	1
Citric acid	1	1	1	1
Ammonium	2	2	2	2

FM = Finger millet

Chemical analysis

Moisture, protein, lipids, fiber and ash contents of (corn flour, rice flour and finger millet flour) and their finger millet chips were determined according to **[26].** Total carbohydrates were estimated using a formula based on differences.

Carbohydrates = 100 - (fat + protein + moisture + ash).

Energy value of free gluten chips was evaluated by multiplying carbohydrates and protein by 4.0 and fat by 9.0 according to the methods of **[26].**

Minerals as calcium (Ca), phosphorous (P) and iron (Fe) contents of corn, rice, finger millet flour and its free gluten chips were determined by utilizing an atomic absorption spectrophotometer (Perkin Elmer 2380) in accordance with the technique of **[26].**

Physical evaluation of finger millet chips

Physical evaluation of gluten free chips as diameter (W) was identified by caliper (HL 474938, STECO, Germany). thickness (T) and volume (v) and spread ratio as W/T were evaluated in accordance to **[27]**.

The texture profile analysis of gluten- free chips was carried out utilizing Stable Microsystems' TA-XT2 Plus texturometer. Using a flat probe with a 75 mm diameter (P/75), the test comprised two compression cycles spaced five seconds apart. 30 kg force load cell, pre-test, test, and post-test speeds of 1.0 mm/s, distance of 4 mm, and trigger force of 0.1 N were the test settings. The characteristics of texture include cohesion, chewiness, hardness, resilience, and springiness were determined using formulae based on **[28].**

The color of gluten -free chips were carried out in triplicate utilizing a colorimeter (CR-400, Konica Minolta, Japan), affording by **[29].** Several color parameters were noted as: L* = lightness (0 = black, 100 = white), a* (+a* = redness, -a* = greenness), and b* (+b* = yellowness, -b* = blueness).

Water activity of gluten-free chips was determined by recording data on water loss or gain per gram of samples by utilizing the AW SPRINT TH-500 water activity monitoring according to **[30].**

Sensory evaluation of finger millet chips

Sensory evaluation of gluten-free chips was conducted in National Research Center department of food technology using 10 panelists according to the method of **[31]** Four coded samples of chips were presented to each of the panelist and they were asked to assess the chips for color, texture, crispness, taste, aroma and overall acceptability using 7-point hedonic scale (0-1 = Dislike very much, 2- 2.9 = Dislike moderately, 3-3.9 = Dislike slightly, 4-4.9 = Neither like nor dislike, 5-5.9 = Like slightly, 6-6.9 =Like moderately, 7 = Like very much), for the assessment.

Statistical analysis

The statistical package for social science (SPSS) version 17.00, developed by SPSS Inc. in Chicago, IL, USA, was used to analyze all data at the 0.05 level. The means ± standard deviation (SD) was used to express the results. One-way analysis of variance (ANOVA) for continuous variables was used to analyze the data in accordance with **[32].**

3- RESULTS AND DISCUSSIONS

Chemical composition of raw materials

Date in Table (2) displayed that the chemical composition of yellow corn, white rice, and finger millet flour, on dry basis. The findings showed that the highest contents of moisture, protein fat and ash are found in finger millet flour flowed by corn flour then rice flour. Also, rice flour had the highest contents of carbohydrate followed by yellow corn flour and then finger millet flour, but corn flour has the highest content fiber flowed by millet flour then rice flour. The outcome of finger millet flour is harmony with those of **[33]** who found that finger millet flour contains 2.1**%**, 2.8%, 7.8%, 13.6%, and 63.2% ash, fiber, fat, protein, and starch respectively. Besides, the result of corn flour is in agree with that of **[34]** who found that corn flour contain 16.19%, 0.25 %, 7.75%, 0.32%, 71.10 % moisture, ash, protein, fat, and carbohydrates respectively. The results of rice flour are in harmony with that of **[35]** who found that rice flour content (9.79-10.53%), (0.554-1.442%), (6.94 -10.21%),**(**1.68- 3.16**%)**, **(**1.07-3.64%**)** ,**(**71.20 -79.68%**)** moisture, ash, protein, fat, fiber and carbohydrates respectively.

Table (2). Chemical composition of raw materials (on dry basis).

Materials	Chemical composition g/100g					
	Moisture	**Protein**	**Fat**	**Ash**	**Fiber**	**Carbohydrate**
Corn flour	11.0 [b] ±0.09	9.25 [b] ±0.03	1.32 [b] ±0.05	0.85 [b] ±0.09	1.57 [a] ±0.05	76.01 [b] ±0.07
Rice flour	10.8 [c] ±0.02	6.77 [c] ±0.04	0.88 [c] ±0.03	0.38 [c] ±0.07	0.47 [c] ±0.03	80.7 [a] ±0.09
Finger millet flour	12.8 [a] ±0.03	11.41 [a] ±0.06	1.74 [a] ±0.07	2.29 [a] ±0.02	1.49 [b] ±0.05	70.27 [c] ±0.10
LSD	0.244	0.084	0.081	0.078	0.079	0.093

Mineral contents of raw materials

Date in Table (3) showed that the minerals contents (calcium, magnesium, zinc and iron) of yellow corn, white rice, and finger millet, on dry basis. The results indicated that the finger millet flour has the highest contents of calcium, magnesium, zinc and iron compared to other flour study. Also, the outcome of minerals contents of corn flour is in contract with result of **[36]** who found that corn flour contains Zn (2.67 mg/kg), and Fe (1.44 mg/kg) Also, the results of minerals contents of finger millet flour is in harmony with those of **[37]** who found that finger millet flour contain Fe (3.97–8.04 mg/100g), Zn (2.08– 4.50 mg/100g), Ca (318–659 mg/100g). The results of minerals content of rice flour agreed with those of **[38]** who found that rice flour contain Fe (0.7 mg/100g), Zn (1.3 mg/100g), Mg (64 mg/100g).

Table (3). Mineral contents of raw materials mg/100g (on dry weight basis).

Materials	**Ca**	**Mg**	**Zn**	**Fe**
Corn flour	14.20 [e] ±0.76	31.76 [b] ±0.46	1.54 [b] ±0.13	3.35 [b] ±0.26
Rice flour	46.49 [d] ±0.36	6.28 [c] ±0.22	0.94 [c] ±0.09	1.18 [c] ±0.05
Finger millet flour	208.48 [a] ±0.86	45.95 [a] ±0.96	2.00 [a] ±0.06	8.20 [a] ±0.16
LSD	0.005	0.009	0.007	0.0001

Chemical composition and nutrition value of finger millet chips

Date in Table (4) presented that the chemical composition and nutrition value of finger millet chips as affected by replacing corn and rice flour by finger millet at levels 0, 10, 15, and 20%. The results point to that increasing the amount of finger millet causes a progressive decrease in moisture and carbohydrate content, while protein, fat, ash, and fiber content are gradually increased. This result could be to that finger millet flour has the highest contents of fat, protein, and ash in comparison to those of corn flour and rice flour as presented in Table (2). So, the chips contain 20% FM has the highest contents of fat, protein, ash and fiber, but it has the lowest contents of moisture and carbohydrate compared to another chips sample. This result agrees with that **[39]** they stated that adding finger millet at different levels caused to increase in contents of protein, ash, and fiber of chips samples. On the other hand, carbohydrates content is decreased regularly with increasing level of finger millet replacement.

In the same Table (4) it is showed that the values (kcal/100g) are gradually increased as increasing levels of finger millet flour, it is due to that finger millet has the highest contents of protein and fat compared to those of corn flour and rice flour as presented in Table (2), So GDR energy values are gradually decreased as rising the levels of finger millet flour. Furthermore, the GDR protein values are slightly reduced as rising levels of finger millet flour. That result is due to increasing protein content as increasing levels of replacement as show in Table (4). So, the sample contain 20% FM has the highest energy values, but it has lowest GDR energy and GDR protein compared to another chips sample. All the results are in agreement with those **of [40]** they reported that replacing of rice flour with millet flour improving the nutrient value of flat bread.

Table (4). Chemical composition and nutrition value g/100g of finger millet chips.

Sample	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate	(Kcal /100gm)	GDR Energy	GDR Protein
Chips 0% FM	6.85[a] ± 0.2	7.01[d]± ±0.24	19.95[d] ±0.09	0.62[cd] ±0.14	1.51[c] ±0.34	64.06 [a] ± 0.4	464 [c] ± 0.10	625.23 [a] ± 0.10	898.72 [a] ± 0.10
Chips 10% FM	6.79 [ab] ±0.12	7.35 [c] ±0.14	20.35 [c] ±0.05	0.76 [c] ±0.06	1.64 [b] ±0.05	63.11 [ab] ±0.04	465 a ± 0.10	623.67 [f] ± 0.17	857.14 [b] ± 0.15
Chips 15% FM	6.56 [b] ±0.03	7.85 [b] ±0.04	20.65 [b] ±0.05	0.96 [b] ±0.06	1.72 [ab] ±0.25	62.26 [b] ±0.14	466 [a] ± 0.10	621.93 [e] ± 0.13	802.55 [c] ± 0.11
Chips 20% FM	6.41 [c] ±0.04	8.15 [a] ±0.05	21.05 [a] ±0.09	1.26 [a] ±0.03	1.85 [a] ±0.03	61.28 [bc] ±0.0.25	467[a] ± 0.11	420.76 [d] ± 0.10	773.01 [c] ± 0.12
LSD	0.031	0.017	0.088	0.071	0.213	0.0234	0.051	0.131	0.122

FM: finger mille. GDR: Grams consumed to cover the daily requirement.

Minerals content of finger millet chips

Date in Table (5) showed that the contents of mineral (calcium, magnesium, zinc and iron) of finger millet chips are gradually increased as replacement levels of finger millet flour, this outcome may be due to finger millet flour contains the largest amounts of (magnesium, calcium, zinc and iron) in compared to those of corn flour and rice flour as presented in Table (3). So, the sample contain 20% FM has the highest contents of the minerals in compared to another chips sample. This result is agreed with that found by **[41]** who described that increasing percentage of millet flour in cookie and bread caused increasing proximate composition, minerals and nutrients. Also, the results are agreed with those of **[42]** who reported that addition finger millet flour caused increased total mineral, calcium, iron and zinc content of cookies. Also, **[40]** who reported that replacing rice flour with millet flour in flat bread caused increasing in contents of calcium, iron and zinc.

Table (5). Minerals content of finger millet chips mg/100g

Sample	Ca	Mg	Zn	Fe
Chips 0% FM	47.16 ^{d} ± 0.34	6.49 ^{d} ± 0.19	0.51 ^{c}± 0.82	1.12 ^{b} ± 0.18
Chips 10% FM	51.64 ^{c} ± 0.60	8.35 ^{c} ± 0.32	0.79 ^{bc} ± 0.87	1.23 ^{ab} ± 0.13
Chips 15% FM	66.92 ^{b} ± 0.89	9.65 ^{b} ± 0.15	0.90 ^{b} ± 0.60	1.34 ^{ab} ± 0.21
Chips 20% FM	81.93 ^{a} ± 0.69	12.06 ^{a} ± 0.92	1.07 ^{a} ± 0.58	1.49 ^{a} ± 0.11
LSD	0.001	0.007	0.008	0.001

FM: finger millet

Physical characteristics of finger millet chips

Since physical appearance is utilized to judge a cracker just before the sense of taste. Also, physical appearance is significant determining factor of purchaser marketability and satisfactoriness of chips **[43].**

Date in Table (6) indicated that the physical properties of finger millet chips, as impacted by replacing rice and corn flour by finger millet flour. The results showed that there are non-significant differences in the weight, volume, and specific volume, but the diameter and spread ratio are gradually decreased as increasing levels of finger millet flour, but there are gradually increased in thickness. So, the chip samples have the highest diameter and spread ratio values, while, it has the lowest thickness compared to another chips sample. These results are agreed with those of **[39]** who establish that when levels of finger millet flour are increase in the chips the diameter and spread ratio are gradually decreased this result is may be due to its high content of protein that propensity to absorb water **[44]**.

Table (6). Physical characteristics of finger millet chips

Sample	Weight (g)	Volume (cm3)	Specific volume (v\w)	Diameter (cm)	Thickness (cm)	Spread ratio
Chips 0% FM	11.20 ^{a} ±0.03	30.67 ^{a} ±0.03	2.74 ^{a} ±0.03	4.73 ^{a} ±0.0	0.99 ^{c} ±0.03	4.78 ^{a} ±0.03
Chips 10% FM	11.17^{a} ±0.03	30.33 ^{a} ±0.29	2.72 ^{a} ±0.05	4.72 ^{a} ±0.02	1.03 ^{ab} ±0.06	4.58 ^{b} ±0.02
Chips 15% FM	11.14 ^{a} ±0.03	30.03 ^{a} ±0.19	2.70 ^{a} ±0.05	4.67 ^{a} ±0.07	1.07 ^{b} ±0.06	4.36 ^{c} ±0.02
Chips 20% FM	11.06 ^{a} ±0.06	29.55 ^{a} ±0.16	2.67 ^{a} ±0.06	4.63 ^{b} ±0.08	1.11 ^{a} ±0.05	4.17 ^{d} ±0.06
LSD	0.091	0.096	0.088	0.031	0.09	0.047

FM: finger millet

Texture of finger millet chips

Texture is one of the significant evaluations of crackers. Texture can affect by processing, handling, shelf-life stability, and it can be as an influential reason of consumer acceptability of cracker consumption **[45].**

Date in Table (7) showed that the effect texture of finger millet chips. The results presented that there are non-significant variances in the adhesiveness and resilience, but there are gradually increased in hardness and factorability as increasing levels of finger millet flour. So, the chip sample contain 20% FM has the highest values on hardness, adhesiveness, resilience and factorability as compared to other chips samples. The results of hardness are agreed with those of **[21]** who reported that the highest hardness was gotten for finger millet compared to other flour, it may be due to finger millet had the highest carbohydrate and fiber compared to others Also, the results of adhesiveness are agree with of [**46]** who reported that the adhesiveness increased in biscuit contain finger millet flour because it has low viscoelastic. As well as **[47]** stated that the composite cracker from finger millet flour had better surface appearances, mouth feel and crispiness.

Table (7) Texture of finger millet chips

Sample	Hardness Cycle1 (N)	Adhesiveness (mJ)	Resilience	Factorability (N)
Chips 0% FM	13.35 [d] ± 0.03	0.00 [a] ± 0.03	0.07[bc] ± 0.03	4.08 [c] ± 0.03
Chips 10% FM	15.33 [c] ± 0.03	0.00 [a] ± 0.03	0.08 [bc] ± 0.01	4.10 [c] ± 0.03
Chips 15% FM	17.33 [b] ± 0.02	0.01 [ab] ± 0.04	0.13 [b] ± 0.01	5.09 [b] ± 0.06
Chips 20% FM	21.64 [a] ± 0.14	0.10 [a] ± 0.04	0.29 [a] ± 0.02	5.85 [a] ± 0.03
LSD	**0.083**	**0.087**	**0.058**	**0.122**

FM: finger millet N: Newton units mJ: Millijoule units N: Newton unit

Color values of finger millet chips

Food product color is the first characteristic that influences the acceptability of consumers **[48].** Date in Table (8) exposed that the (L*) lightness and (b*) yellowness values of chips samples are reduced but the redness (a*) value is increased as increasing levels of finger millet flour**.** This result might be due to the color of millet flour is darker than that of corn flour or rice flour. So, the chips have the highest values (L*) and (b*) but it has the lowest value of (a*) in compared to other chips samples also, baking caused decrease on lightness. The result of chips lightness is agreed with that of **[49]** who found that thermic treatment as baking furthermore, has a significant reducing the brightness of chips due to reaction of Maillard and reducing sugar-amino acid interact that producing brown compounds or melanoidins.

Table (8) Color values of finger millet chips.

Sample	L	a	b
Chips 0% FM	63.29 [a] ± 0.03	4. 59 [a] ± 0.03	33.17 [a] ± 0.03
Chips 10% FM	62.93 [b] ± 0.03	5.64 [b] ± 0.03	32.38 [a] ± 0.02
Chips 15% FM	59.92 [c] ± 0.10	6.77 [c] ± 0.06	29.18 [b] ± 0.07
Chips 20% FM	53.74 [d] ± 0.04	7.55 [d] ± 0.06	22.17 [c] ± 0.02
LSD	0.143	0.098	0.078

FM: finger millet

Moreover, the result of chips redness is agreed with that of **[50]** who found that the color of biscuits color being dark as affecting by adding millet flour, as well as **[51]** who found that the rise of a* values show that the darkness crackers was consistent with the finger millet flour level.

Water activity of finger millet chips

Bakery product as biscuits must have low water activity, which is defined as the amount of binding water present in the food and its capacity to act as a solvent and participate in chemical reactions. Bacteria normally require at least 0.91 water activity to grow, whereas fungi require at least 0.7 water activity **[52].**

Date in Table (**9**) showed that the water activity of all finger millet chips is below 0.5 water activity So, microorganisms cannot survive **[51].** Also, the results showed that water activity is decreased as increasing levels of finger millet flour, So, the sample containing 20% FM **i**ndicate the lowest of water activity value in compared to other chips samples**.** This is agreed with **[51]** who reported that all finger millet flour incorporated chips are considered as microbiologically stable products. These finding was supported by **[52]** who reported that when the water activities of food products less than 0.6, it is considered as microbiologically stable.

Table (9). Water activity of finger millet chips.

Sample	Aw	C
Chips 0% FM	$0.469^{a} \pm 0.007$	$18.53^{a} \pm 0.005$
Chips 10% FM	$0.466^{a} \pm 0.005$	$18.58^{a} \pm 0.003$
Chips 15% FM	$0.460^{a} \pm 0.005$	$18.66^{a} \pm 0.003$
Chips 20% FM	$0.457^{a} \pm 0.003$	$18.69^{a} \pm 0.002$
LSD	0.125	0.049

FM: finger millet

Sensory evaluation of finger millet chips

Sensory assessment is a vital importance characteristic of novel product development and to know customer acceptability and their favorites depend on their likes and dislikes **[21].**

Date in Table (10) presented the mean score for color, texture, taste, crispness, aroma and overall acceptability of finger millet chips. These results of millet chips indicated that there are non-significant differences in texture, taste, and crispness scores, but there is significant increase in aroma score as increasing levels of finger millet flour**.** These outcomes could be the result of the finger millet has tannins compounds have been affect in color, flavor, nutritional quality of products prepared as found by **[53]** Also, sponge cake fortification with finger millet has dark color in compared to wheat cake **as** reported by **[54].** Correspondingly, this result is harmony with that of [**21]** who reported that wheat biscuit contain finger millet has a low score in color due to dark crumb and crust color. Moreover, all recipes of chips are acceptable, nevertheless the best formula of chips which contain 15% finger millet compared to other chips samples. This result is line up with **[40]** who found that the replacing of rice flour with millet flour in flat bread has acceptable sensory appearances specially 10% has the highest acceptability.

Table (10): Sensory evaluation of finger millet chips.

Sample	Color (7)	Texture (7)	Taste (7)	Crispness (7)	Aroma (7)	Overall acceptability (7)
Control chips 0% FM	6.13 [a] ±0.03	6.20 [a] ±0.12	6.08 [a] ±0.12	6.07 [a] ±0.12	6.22 [a] ±0.12	6.12 [ab] ±0.12
Chips 10% FM	6.11 [a] ±0.03	6.22 [a] ±0.09	6.08 [a] ±0.12	6.10 [a] ±0.17	6.20 [a] ±0.03	6.12 [ab] ±0.13
Chips 15% FM	6.10 [a] ±0.13	6.22 [a] ±0.23	6.07 [a] ±0.32	6.10 [a] ±0.17	6.18 [a] ±0.23	6. 17 [a] ±0.23
Chips 20% FM	6.07 [ab] ±0.03	6.22 [a] ±0.08	6.03 [a] ±0.06	6.10 [a] ±0.06	6.13 [b] ±0.03	6.07 [bc] ±0.13
LSD	0.133	0.093	0.098	0.0143	0.065	0.123

FM: finger millet

CONCLUSION

Finger millet has high nutrition value so, incorporation gluten- free chips with finger millet flour at different levels can improve quality properties as customer acceptance, appearance, physical, and texture. Nonetheless, incorporation by finger millet flour caused significantly improvement in healthy benefit of gluten- free chips

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التركيب الكيميائي والخواص الفيزيقية والحسية للرقائق الخالية من الجلوتين المدعمة بدقيق الدخن

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الملخص العربي

تهدف هذه الدراسة الى تحضير رقائق الدخن الخالية من الجلوتين باستبدال دقيق الأرز الأبيض والذرة الصفراء بدقيق الدخن بمستويات صفر و 10 و15 و20%. تمت دراسة التركيب الكيميائي و القيمة الغذائية والخصائص الفيزيقية والحسية لرقائق الدخن. أظهرت النتائج أنه كلما زادت مستويات احلال دقيق الدخن كلما حدث زيادة تدريجيَّة في محتوى البروتين والرماد والدهون والألياف بينما حدث انخفاضا تدريجيا في محتوى الرطوبة والكربوهيدرات. وبالتالي، حدث انخفاض فى قيم GDR للبروتين و GDR للطاقة. بالإضافة إلى ذلك، حدث زيادة تدريجيَّة في محتوى المعادن مثل الكالسيوم والمغنيسيوم والزنك والحديد. كما، أظهرت نتائج الخواص الفيزيقية للرقائق انه حدث انخفاضا تدريجيًا فى القطر ، بينما حدث زيادة تدريجية فى السمك. و لذلك، انخفض معدل الانتشار بزيادة مستويات التدعيم بدقيق الدخن. اما بالنسبة لخواص النسيج حدث زيادة تدريجية في كل من الصلابة و درجة الارتباط. واذلك أظهرت نتائج اللون للرقائق انخفاضا فى قيمتي الاصفرار (b*) و الشفافية (L*)، بينما حدث زيادة في قيمة الاحمرار (a*) نتيجة لزيادة مستويات دقيق الدخن. وأظهرت النتيجة انخفاض فى نشاط الماء للرقائق بزيادة مستويات دقيق الدخن. وكذلك، اوضحت نتائج الخصائص الحسية أن جميع الرقائق مقبولة حسيا. و كانت الرقائق التي تحتوي على 15٪ من دقيق الدخن اعلى قبول حسي بالمقارنة بعينات الرقائق الأخرى. و عموما ، استبدال دقيق الدخن بدلا من دقيق الذرة الصفراء أو دقيق الأرز يرفع القيمة الغذائية والخصائص الفيزيائية والحسية لرقائق الخالية من الجلوتين.

الكلمات المفتاحية: خالي من الجلوتين - الذرة - الأرز - الدخن - رقائق.