كلية معتمدة

Development of Functional and Rheological Properties of Bakery Products from Maize Flour and Powders of Lentil and Chickpea

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Abstract

Maize is one of the most important strategic crops in Egypt and comes in second after wheat. It is widely used for producing bread, morning cereals, and snacks. So, this work aims to fortify maize flour (MF) with common legumes powder (roasted chickpea "RChP" and red lentil "RLP") to enhance its nutritional value. And investigate the impact of incorporating 15%, 30% of RChP and RLP into the MF on the chemical, functional, and reological properties of the dough. Also, sensory evaluation of the final product (biscuits and crackers) will be within the scope of this investigation. Results indicated that MF had a higher percentage of carbohydrates, moisture, and fibre content (71.95, 10.55, and 3.15%, respectively) than RChP and RLP On the other hand, legumes (RLP and RChP) significantly ($p \leq 0.05$) recorded the highest protein ratio (23.95 and 21.85, respectively) compared to maize flour (9.15%). Legumes such as lentil and chickpea could be a proper source of potassium, calcium, phosphor, and iron. RChP presented high contents of 885, 151, 382, and 9.3 mg.100 g^{-1} for K, Ca, P, and Fe, respectively. As regards the farinograph, the highest development time and stability time were 3.71 and 6.32 min respectively for RChP 30%; the lowest values were 2.5 and 3.71 min, respectively, for MF. Also, observed that incorporating checkpea and lentil powder in percentages of 15% and 30% in dough increased the extensibility from 112.35 mm for control to 150.68 and 152.88 mm for dough containing 15% and 30% RChP respectively, and 147.00 and 151.51mm for dough containing 15% and 30% RLP respectively. In conclusion, the results suggest that by incorporating RChP and RLP with MF, it is possible to improve the nutritional value (protein and minerals) and functional properties of biscuits and crackers and enhance their sensory characteristics.

***Key words*:** legumes, corn flour, nutritional value, sensory characteristics, composite flour, physical and chemical properties.

1. **Introduction**

Maize is one of the most important strategic crops in Egypt and comes in second after wheat. In many areas, it is used in human food and animal feed **(Elfar *et al.*, 2023)**. They are also involved in many industries, such as oil, starch, and many others. Shamia corn is one of the most important pillars of Egyptian food security. Egypt's total maize production in 2021 was 7,748 tonnes **(El-Bahenasy, 2023).**

There is considerable interest from the state to develop the maize crop to achieve food security, confront the steady population increase, and achieve some self-sufficiency to reduce the food gap **(Elfar *et al*., 2023).**

Maize flour is a common ingredient in many bakery products, such as bread, cookies, pies, pastries, and muffins. Most maize bread formulas add wheat flour to increase dough elasticity and create a more aerated, light product, or are enriched with vitamins, riboflavin, niacin and minerals to improve quality (**Serna-Saldivar, 2016).**

Dried legume seeds are generally considered a traditional oriental food; it has been used for the preparation of various traditional foods such as an ingredient in bakery products, children food, and imitation milk **(Kumar *et al*., 2015).** Chickpeas, lentils, and dried peas are examples of pulses, which are legumes (seeds grow inside pods). Proteins, fibre, complex carbs, vitamins, and vital minerals are all abundant in pulses **(Singh, 2017).** Additionally, it contains "phytochemicals" that may lower the chance of developing certain cancers and disorders **(Bresciani and Marti, 2019)**

Pulses can be incorporated into a variety of special diets for people with celiac disease and diabetes because of their nutritional content, some studies suggested that pulses have a lower blood sugar index and may lead to stable sugar levels in blood after meals **(Bresciani and Marti, 2019)**. Plant proteins are more affordable than animal proteins, making them a significant source of protein for diet in many impoverished nations **(Joshi *et al*., 2015).**

Lentil (*Lens culinaris L.*) is a traditional dietary ingredient that belongs to the *Leguminoceae* group and contains a high insoluble fibre content of around 93 to 99.7%, making it a good source of fibre **(Bednar *et al*., 2001)**. Studies have demonstrated that lentil consumption has health benefits, including a decrease in the risk of cardiovascular disease, gastrointestinal disorders, diabetes, cancer, osteoporosis, hypertension, and LDL cholesterol **(Boye *et al*., 2010)**.

In terms of global economic perspective, chickpea (*Cicer arientum L.*) is the fifth most valuable food and the most important legume (**Hefnawy *et al*., 2012**). It contains protein, complex carbohydrates with a low glycemic index, and is almost free of anti-nutritional factors (**Muzquiz and Wood, 2007**). Supplementing chickpea powder with cereal flour improves the protein qualities, vitamins, and minerals (**Kaur and Prasad, 2021**). Roasted chickpea is used as ready-to-eat snacks or in the manufacture of many other snacks. The roasting procedure of chickpea could lead to boosted total content and antioxidant activity and retained amounts of minerals (magnesium, phosphorous, potassium, and iron) (**Hassan *et al*., 2021**), also could be enhanced amino acid content (tyrosine, lysine, valine, cysteine, and leucine) compared to raw seeds (**Khattab *et al*., 2009**).

Therefore, the present study aims to enhance the nutritional value of bakery products produced from maize by incorporating various levels of legume powders (red lentil and chickpea). Also, studies of the chemical, functional, reological properties and sensory evaluation of the final products (biscuits and crackers) will be within the scope of this investigation.

2. Materials and Methods

2.1. Materials

Maize flour and other ingredients, including red lentils and roasted chickpeas, were purchased from the El-Masria hypermarket in Minia City, Minia Governorate, Egypt.

2.1.1. Reagents and chemicals

All solvents and chemicals were obtained from El-Gomhoryia Company for Trading Drugs, Chemicals and Medical Instruments, Cairo, Egypt.

2.2. Methods

2.2.1. Preparation of red lentil and chickpea Powders

The roasted chickpea and dry lentil samples were washed to remove foreign substances and broken seeds before being crushed with a mixer blender (Toshiba Elaraby, Benha, Egypt). Then placed in a glass jar and kept at 4°C until analysis and preparation of the products.

Photo (1) legumes and their powders

2.2.2. Preparation of biscuits

The method used to prepare the biscuits followed the process suggested by **Aly *et al.*, (2022)** in Table (1) and Figure (1). To create a creamy mixture, butter and sugar were mixed first. The remaining ingredients were then added to form the dough, then rolled with a rolling pin to an even 0.6 cm thickness, cut into small cores and baked at 200ºC for 10 minutes. The biscuits were subsequently cooled and used for sensory evaluations.

Table (1): Formulation of biscuits

Ingredients / Samples	MF (g)	RChP (g)	RLP (g)	Egg (g)	Butter (g)	Suger (g)	Salt (g)	Vanilla (g)
M F 100%	100	—	—	10	50	25	2	**2**
RChP15%	85	15	—	10	50	25	2	**2**
RChP30%	70	30	—	10	50	25	2	**2**
RLP 15%	85	—	15	10	50	25	2	**2**
RLP 30%	**70**	**—**	**30**	**10**	**50**	**25**	**2**	**2**

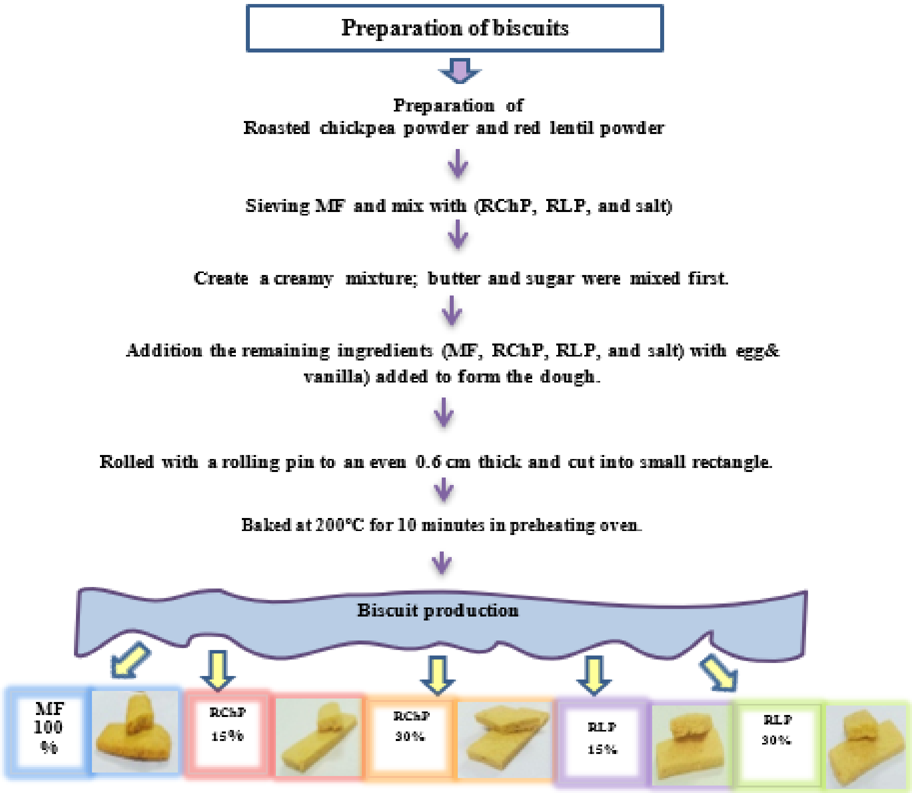


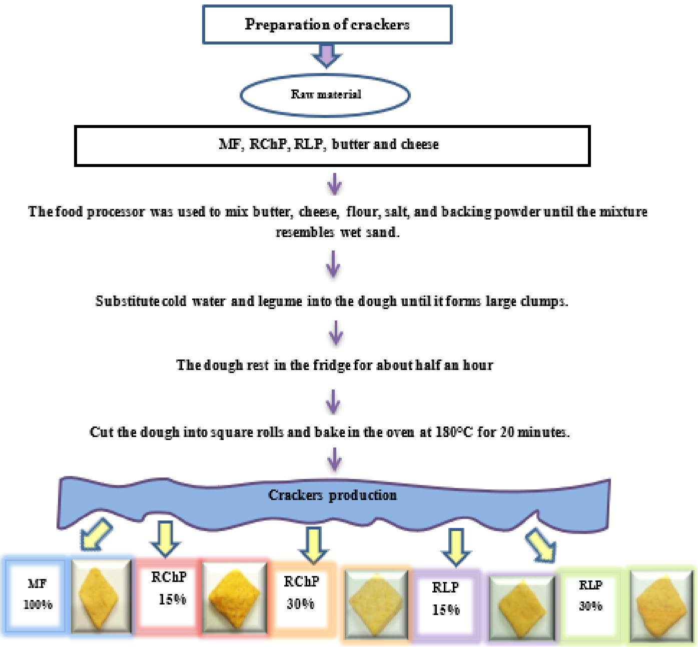
Figure (1): Preparation of biscuit

2.2.3. Preparation of crackers

Crackers were prepared according to **Hussin *et al.*, (2022)** method with some modification as shows in Table (2) Figure (2). The food processor (Toshiba ElAraby, Benha, Egypt) was used to mix butter, cheese, flour, salt, and backing powder until the mixture resembles wet sand. Substitute cold water and legumes into the dough until it forms large clumps; let the dough rest in the fridge for about half an hour. Then cut the dough into square rolls and bake in the oven at 180°C for 20 minutes. After cooling, it was placed in polyethylene bags to be used for sensory evaluation.

Table (2): **Formulation of crackers**

Ingredients / Samples	MF (g)	RChP (g)	RLP (g)	Butter (g)	Cheese (g)	Salt (g)	Backing powder (g)	Water (ml)
M F 100%	100	—	—	36	92	0.5	2	**24**
RChP15%	85	15	—	36	92	0.5	2	**24**
RChP30%	70	30	—	36	92	0.5	2	**20**
RLP 15%	85	—	15	36	92	0.5	2	**24**
RLP 30%	**70**	**—**	**30**	**36**	**92**	**0.5**	**2**	**24**



Figuer (2): Preparation of crackers

2.2.4. Proximate chemical composition

AOAC, (2005) method was used to determine moisture, protein, fibre, fats, and ash contents. Carbohydrate was calculated as follows:

Carbohydrate (%) = 100 - (Moisture% +Fat% + Protein% + Fiber% + Ash%)

2.2.4.1. Minerals Content

Magnesium, potassium, sodium, calcium, zinc, and iron were determined using Atomic Absorption Spectrophotometer, Pyeunican SP1900, according to methods of **Brandifeld and Spincer, (1965)**. Phosphorus (g/100g dry weight) was determined calorimetrically according to **Jackson, (1958). 2.2.5. Determination of water and oil holding capacity (WHC and OHC).**

WHC and OHC of the MF, RChP, and RLP were determined using the method described by **Giami *et al.*, (1994)**; WHC and OHC are calculated after weighing the residues obtained after centrifugation.

2.2.6. Rheological properties of dough

Farinograph measurement folowing methods of **AACC, (1983)** and **ICC, (1992),** were examined the dough mixing properties of different MF, RChP and RLP blends by used the brabender farinograph mixer type's 300 H (Brabender, Duisburg, and Germany). Also, extensograph test was carried out on a brabender extensograph model 8600, (Bratendes, Duisburg, Germany) to determine the maximum resistance to extension extensibility and strength of the dough (energy).

2.2.7. Evaluation of sensory characteristics of biscuits and crackers

Sensory evaluation was carried out using 20 panel tests at Minia University's Home Economics Department, Faculty of Specific Education. Each person got five samples of biscuits and crackers in a closed packet coded with a unique number. Using a

1–10 scale, each panellist evaluated the products' taste, odor, color, texture, and general approval.

2.2.8. Ethical Approval

The experiments and sensory evaluation in the present study were ethically approved by the Ethics Committee of the Scientific Research, Faculty of Specific Education - Minia University.

2.2.9. Statistical analyses

All measurements were taken in triplets and recorded as mean and standard deviation. The statistical evaluation was carried out using the General Linear Model programme and the SAS system **(SAS, 2003).**

3. Results and Discussion

3.1. Chemical analysis and minerals content of MF, RChP, and RLP

The proximate analysis of the selected samples is presented in Table (3). Data indicated that maize flour had a higher percentage of carbohydrates, moisture, and fiber content (71.95, 10.55 and 3.15 %), respectively than RChP and RLP. On the other hand, pulses (RLP and RChP) significantly ($p \leq 0.05$) recorded the highest protein ratio (23.95 and 21.85), respectively compared to maize flour (9.15%). Our results agreed with those of **Alcântara *et al*., (2017)** who indicated that maize has low protein quality and includes tiny levels of important amino acids such as lysine and threonine. So, combining legume flour with maize or wheat flour may assist in increasing the protein quality and offer complete nutrition for persons at risk of protein deficiency **(Kaur and Prasad, 2021**). As regards the results, small variances were observed between MF and RChP in fat content, while the RLP presents the lowest percent of fat (0.86%).

Table (3) Chemical composition and minerals of maize flour and (roasted chickpea, red lentil) powders

Samples	**MF**	**RChP**	**RLP**
Parameters ($g.100g^{-1}$ dry sample)			
Moisture	10.55 ± 0.76^{a}	9.53 ± 0.65^{b}	10.42±0.85^{a}
Total protein	9.15 ± 0.54^{c}	21.85 ±1.02^{b}	23.95± 1.23^{a}
Fat	3.85 ± 0.44^{a}	3.48 ± 0.22^{a}	0.86 ± 0.09^{b}
Fiber	3.15 ± 0.25^{a}	3.01 ±0.25^{a}	2.18 ± 0.24^{b}
Ash	1.35 ± 0.14^{c}	2.72 ±0.45^{a}	2.03 ± 0.18^{b}
Carbohydrates	71.95 ± 1.63^{a}	59.41 ±1.23^{b}	60.56±1.31^{b}
Minerals content ($mg.100g^{-1}$)			
K	65 ± 1.25^{c}	885± 15.3^{a}	668± 10.24^{b}
Na	73± 2.5^{a}	21± 0.35^{c}	54± 1.32^{b}
Ca	25 ± 0.75^{c}	151± 1.25^{a}	75±8.2^{b}
Mg	173 ± 1.03^{a}	135±2.03^{b}	95± 4.62^{c}
P	78 ± 0.87^{c}	382± 4.35^{a}	362±11.46^{b}
Fe	2.67± 0.32^{c}	9.3±0.34^{a}	8.64±0.46^{b}
Zn	77 ± 0.02^{a}	2.8± 0.03^{b}	3.55±0.14^{b}

Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same row are significant at $p \leq 0.05$.

Macroelements (potassium, calcium, magnesium, and phosphorus) and microelements (manganese, iron, and zinc) play critical roles in the body's metabolism and homeostasis **(Bhandar and Raj Banjara, 2015)**. Deficiencies of these constituents can lead to an increase in common disorders and disease symptoms **(Mohammad *et al*., 2017).**

From the observations of Table (3), MF presents a low mineral content of (K, Ca, P, and Fe) comparing to chickpea and lentil powders, also could be noticed that RChP and RLP could be proper sources of K, Ca, P, and Fe RChP presented large contents of 885, 151, 382, and 9.3 $mg.100\,g^{-1}$ for K, Ca, P, and Fe respectively, whil RLP presented medium contents in 668, 75, 362, and 8.64 $mg.100\,g^{-1}$.

3.2. Chemical analysis and minerals content of flour fortified with RChP and RLP

Data in Table (4) indicated that replacement of maize flour with 15% and 30% of other legumes powder (RChP and RLP) led to increase values of protein, and ash content. The protein content increased from 9.15 to 11.06 and 12.97 g.100g^{-1} with 15%and 30% incorporation of RChP respectively, and 11.37 and 13.60 g.100g^{-1}, with 15% and 30% incorporation of RLP respectively. It is probably due to their high content of protein and ash content (see Table 3). Many similar studies indicated that incorporation of legumes into flour enhances their nutritive value. For example, **Ettoumi and Chibane, (2015)** reported that lentil, pea, and chickpea whole flours are rich in protein and poor in fat and serve as cheap and alternate sources of proteins. The addition of legume flour improves vitamins and minerals and is therefore advantageous in providing good nutrition for people who are at risk of being protein deficient **(Kaur and Prasad, 2021)**. Maize is a rich source of carbohydrates when compared to checkpea and lentil (**Makram *et al*., 2023**). So, the addition of RChP and RLP at levels 15% and 30% led to decrease the percentage of carbohydrate in all samples.

Results from Table (4) shows that lugumes powder examined contained a higher amount of minerals than the control flour. So, the effect of these legume powders (RChP and RLP) at different replacement levels (15 and 30%) on the meniral content of maize flour was evaluated. The potassium, calcium, phosphore, and iron contents of samples increased significantly ($p \leq 0.05$) with increasing replacement levels of maize flour by legume powders. Potassium increased more than twice by increasing the amount of flour incorporated with different levels of RChP and RLP; the highest level was recorded in the RChP 30% sample (311.75 mg/100 g), followed by the RLP 30% sample (245.9 mg/100 g). Our result is in the same line with **Moussou *et al*., (2019**) who mentioned that legumes (lentil, chickpea, and pea) contained a higher amount of potassium, calcium, and phosphorus than other macroelements and lower amounts of copper and zinc.

Table (4) Proximate composition of MF fortified with RChP and RLP

Samples	M F 100%	RChP 15%	RChP 30%	RLP 15%	RLP 30%
Parameters (g.100g^{-1})					
Moisture	10.55 ± 0.76	10.40±0.45	10.25 ±0.31	10.53 ±0.37	10.52 ±0.21
Total protein	9.15 ± 0.54^{d}	11.06±0.31^{c}	12.97±0.11^{b}	11.37±0.21^{c}	13.60±0.20^{a}
Fat	3.85 ± 0.44^{a}	3.75±0.25^{a}	3.64±0.12^{a}	3.40±0.21^{ab}	2.96±0.24^{b}
Fiber	3.15 ± 0.25^{a}	3.13±0.14^{a}	3.11±0.06^{a}	3.01±0.09^{ab}	2.86±0.43^{b}
Ash	1.35 ± 0.14^{b}	1.56±0.25^{ab}	1.77±0.13^{a}	1.45±0.16^{b}	1.56±0.19^{ab}
Carbohydrates	71.95 ± 1.63^{a}	70.07±0.87^{ab}	68.19±0.65^{b}	70.24±0.76^{ab}	68.54±0.66^{b}
Minerals content (mg.100g^{-1})					
K	65 ± 1.25^{e}	188±0.25^{c}	311.75±0.31^{a}	155.72±0.37^{d}	245.9±0.20^{b}
Na	73± 2.5^{a}	65.2±0.0.44^{ab}	57.4±0.21^{b}	70.15±0.21^{a}	67.30±0.31^{ab}
Ca	25 ± 0.75^{d}	43.9±0.25^{b}	62.8±0.11^{a}	32.5±0.11^{c}	40.00±0.20^{ab}
Mg	173 ± 1.03^{a}	167.3±0.14^{a}	161.10±0.09^{a}	161.03±0.09^{a}	149.60±0.06^{b}
P	78 ± 0.87^{d}	123.60±0.31^{c}	169.20±0.21^{a}	120.60±0.21^{c}	163.20±0.21^{b}
Fe	2.67± 0.32^{d}	3.67±0.20^{e}	4.66±0.11^{a}	3.57±0.20^{c}	4.46±0.11^{b}
Zn	77 ± 0.02^{a}	65.87±0.06^{b}	54.74±0.09^{c}	65.98±0.24^{b}	54.97±0.09^{c}

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same row are significant at p≤0.05.

3.3. Nutritional properties

3.3.1. Nutritional evaluation of MF, RChP and RLP

The nutritional evaluation of MF, RChP, and RLP was investigated in Table (5). Data presented that the energy (Kcal/100g) in MF, RChP, and RLP was 359.05, 354.69, and 345.78%, respectively. The result clarified that MF has the highest energy content (359.05 Kcal/100 g) when compared with RChP and RLP. Our results agree with **Wood and Grusak, (2007)** who found that the energy content of chickpea types ranged from 334 to 446 kcal/100 g, which resembles our results (354.69 kcal/100 g) for energy.

From the results in Table (5), it was noticed that grams daily required (GDR) of MF, RChP, and RLP to obtain the recommended daily allowance of an adult man of energy were (807.69, 817.63, and 838.68g) of MF, RChP, and RLP respectively, while the GDR (g) of MF, RChP, and RLP to obtain the RDA of protein were (690.13, 288.75, and 263.51 g) respectively. The consumption of 100 g from MF, RChP, and RLP will cover 14.52, 34.66, and 38.02 % respectively of the RDA of men in protein. **Kohajdová *et al.*, (2013)** reported that lentil has a high protein content (20–30%), and ash in comparison to wheat flour (**Migliozzi *et al.*, 2015**). Protein is an imperative macronutrient, optimal mixing of proteins from various plant sources can provide enough necessary amino acids to meet human health requirements **(Kumar *et al.*, 2022).** While consuming 100 g of MF, RChP and RLP will cover 12.38, 12.23, and 11.92 % respectively of the RDA of men in energy, that's because of their high content of carbohydrates and protein.

Table (5) Nutritional evaluation of MF fortified with RChP and RLP

RDA 1989	Chemical composition (g/100g)	MF	RChP	RLP
2900Kcal	Energy (Kcal/100g)	359.05±0.4^{a}	354.69±2.31^{b}	345.78±1.12^{c}
	*G.D.R. (g)	807.69±1.92^{b}	817.63±5.33^{b}	838.68±3.08^{a}
	**P.S./100 g	12.38±0.10^{a}	12.23±0.07^{b}	11.92±0.05^{c}
63g	Total protein	9.15 ± 0.54^{c}	21.85 ±1.02^{b}	23.95± 1.23^{a}
	G.D.R. (g)	690.13±24.8^{a}	288.75±13.49^{b}	263.51±13.55^{b}
	P.S./ 100 g	14.52±0.85^{c}	34.66±1.62^{b}	38.02±1.6^{a}
Dry matter (%)		89.45±0.76	90.47±0.65	89.58±0.85

Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same row are significant at $p \leq 0.05$.
*G.D.R. (g): Grams consumed to cover the recommended daily allowance of an adult man according to RDA (1989)
** P.S. /100 (%): Percent satisfaction of RDA of an adult man when consuming 100 grams.

3.3.2. Nutritional evaluation of MF mixed with RChP and RLP at different levels (15 and 30%)

Table (6) shows the effect of the incorporation of different ratios of powders on the nutritional evaluation properties. The results indicated that the energy content ranged from 355.07 to 359.05 Kcal/100g, depending upon the blending proportions, MF (359.05 Kcal/100g), RChP 15% (358.397 Kcal/100 g), RChP 30% (357.74 Kcal/100g), RLP15% (357.06 Kcal/100 g), and RLP30% (355.07 Kcal/100g). The results clarified that the energy content of composite flours decreased with blends with other flours compared to MF.

Table (6) Nutritional evaluation of MF mixed with ChP and RLP at levels (15 and 30%)

RDA (1989)	Chemical composition (g/100g)	M F 100%	RChP 15%	RChP 30%	RLP 15%	RLP 30%
2900Kcal	Energy (Kcal/100g)	359.05 ±0.4[a]	358.39 ±0.23[ab]	357.74 ±0.51[b]	357.06 ±0.15b[c]	355.07 ±0.11[c]
	*G.D.R. (g)	807.69 ±1.92[e]	809.18 ±0.43[d]	810.67 ±0.96[c]	812.34 ±0.24[b]	816.99 ±0.23[a]
	**P.S./100 g	12.38 ±0.10[a]	12.36 ±0.03[ab]	12.34 ±0.02[b]	12.32 ±0.02[bc]	12.25 ±0.01[c]
63g	Total protein	9.15 ± 0.54[d]	11.06 ±0.31[c]	12.97 ±0.11[b]	11.37 ±0.21[c]	13.60 ±0.20 [a]
	G.D.R. (g)	690.13 ±24.8[a]	629.92 ±25.66[b]	569.72 ±20.02[cd]	626.13 ±25.6[bc]	562.14 ±20.07[d]
	P.S./ 100 g	14.52 ±0.85[d]	17.55 ±0.4[c]	20.57 ±0.09[b]	18.05 ±0.35[c]	21.57 ±0.01[a]
Dry matter (%)		89.45 ±0.76	89. 6 ±0.55	89.76 ±0.27	89.47 ±0.52	89.49 ±0.28

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same row are significant at p≤0.05.
*G.D.R. (g): Grams consumed to cover the recommended daily allowance of an adult man according to RDA (1989)
** P.S. /100 (%): Percent satisfaction of RDA of an adult man when consuming 100 grams.

GDR (g) for energy varied from 807.69 to 816.99% depending upon the energy content of each of the blending proportions, i.e., MF100 (807.69 %), RChP15 (809.18%), RChP30 (810.67%), RLP15 (812.34%) and RLP30 (816.99%). So, the percent satisfaction of RDA of an adult man when consuming 100 grams of composite flours consisting of maize, chickpea, and lentil differs according to energy content, the P.S./100g for energy was 12.38, 12.36, 12.34, 12.32, and 12.25 % for MF, RChP15%, RChP30%, RLP15%, and RLP30% respectively.

The results clarified that the protein content of composite flours increased with an increase in the ratio of other powders compared to MF. The high protein content was observed for RLP30% (13.60 g/100g) and the lowest was for MF100% (9.15 g/100 g), which means that the blending of red lentil powder (RLP) greatly increased the nutritional value of MF.

GDR (g) for protein varied from 562.14 to 690.13 % depending upon the protein content of each of the blending proportions, i.e., MF100 (690.13%), RChF15 (629.92%), RChF30 (569.72%), RLF15 (626.13%), and RLF30 (562.14%). So, the P.S./100g for protein was 14.52, 17.55, 20.57, 18.05, and 21.57% for MF, RChF15%, RChF30%, RLF15%, and RLF30%, respectively. It is clear from our previous results, the importance to use RChF and RLF for raising protein content in food products to prevent malnutrition diseases. Our results agreed with **Lu *et al.*, (2020)** who confirmed that chickpea is a functional food and useful source of dietary protein because of its high nutritional value and excellent balance of essential amino acids. Also, **Romano *et al.* (2021)** explained that lentil flour has an excellent and balanced nutritional composition, so that was used in food products such as bread, snacks, cake, pasta, and crackers.

3.4. Functional properties

3.4.1. Water holding capacity.

The term "water-holding capacity" (WHC) refers to a measurement of how much water may be absorbed overall per grame of protein powder. The ability of flours to absorb water provides insight into how certain nutrients and bioactive substances interact with water (**Boucheham *et al*., 2019)**. High WHC flours may be beneficial components in bakery products such as bread because they allow bakers to incorporate more water into the dough, which enhances handling properties and preserves bread freshness (**Ettoumi and Chibane, 2015).**

WHC values for MF, RChP and RLP are present in Table (7). RLP powder WHC (7.11 g water/g sample) was higher than the values found for RChP and MF, (7.06 and 5.89 g/g respectively). As a result, this could be related to lentils' high dietary fibre content, which may play a role in boosting water holding capacity. The high insoluble fiber and ability of proteins to physically bind water in flours are two factors responsible for the high absorption of water and binding capacity **(Afzal *et al*., 2016).** So, results observed that the replacement for maize flour with other legume powder led to increase the values of WHC, these values increase with the increase of RChP and RLP levels.

Table (7) WHC and OHC of different flour samples

Parameters / Samples	WHC (g water/g flour)	OHC (g oil/g flour)
MF 100%	5.89±0.43[b]	2.91±0.24[b]
RChP	7.06±0.24[a]	3.50±0.11[a]
RLP	7.11±0.37[a]	3.41±0.16[a]b
RChP15%	6.00± 0.54[b]	3.01±0.25[ab]
RChP30%	6.11±0.25[b]	3.10± 0.35[ab]
RLP 15%	6.01±0.0.34[b]	3.00±0.0.44[b]
RLP 30%	6.15±0.66[b]	3.05± 0.76[ab]

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same column are significant at $p \leq 0.05$.

3.4.2. Oil holding capacity.

OHC refers to the amount of oil which a flour sample could absorb per unit of weight. High OHC content can enhance a product's taste, maintain flavour, and improve texture (**Boucheham *et al*., 2019).**

Regarding results at Table (7), RChP and RLP have the highest OHC compared to maize flour, so the addition of 15% and 30% of RChP or RLP to MF led to an increase in OHC, this could be due to the levels of protein, which is a hydrophobic substance that gives accessible places for protein to store oil (**Heywood *et al*., 2002)**. Similar comparisons have been reported by **Ettoumi and Chibane, (2015)** indicated that RChP has the highest OHC at different temperatures, followed by pea and lentil, and suggested that there are two factors that impact the WHC and OHC: type of legume and temperature.

3.5. Rheological properties

3.5.1. Farinograph

The reological data in Table (8) shows farinograph characteristics: water absorption, arrival time, dough development time, and stability time. Water absorption is critical for dough texture and efficiency during baking, and it reflects an ideal water-to-flour ratio in dough. Data shows the capacity of flour to absorb water was increased with decreasing levels of MF.our results were agreed with **Makram *et al*., (2023)** who found that WHC was increase with increasing the levels of checkpea and lentil powders. The increasing in water absorption in dough could be princibally attributed to the high fiber content **(Elhassaneen *et al*., 2018).** The amount of time between the beginning of addition water and the maximum constancy right before the initial sign of weakening is known as the farinograph development time **(Abera *et al*., 2017)**. In this study, the highest farinograph development time and stability time values were 3.71 and 6.32 min, respectively for RChP 30%; the lowest values were 2.5 and 3.71 min respectively for MF. This may be due to the high fiber content in maize flour, where fibre significantly hampers protein binding and produces weaker doughs **(Rosell *et al*., 2010)**. These parameters are indicators of the flour strength and quality of protein, so the addition of values of 15% and 30%, RChP and RLP to MF led to strong doughs. Flour with a short dough development time becomes unstable during continuous mixing and produces low-quality dough, whereas flour with a longer dough development time is more stable during mixing and produces high-quality bread **(Aydoğan *et al*., 2015)**.

Table (8) Farinograph parameters of MF fortified with RChP and RLP

Parameters	**Water absorption (%)**	**Arrival time (min)**	**Dough development time (min)**	**Stability time (min)**	**Farinograp quality number**
Samples					
MF100%	39.89 ±0.11[d]	1.21 ±0.16[c]	2.5 ±0.25[b]	3.71 ±0.37[b]	111 ±2.43[c]
RChP15%	52.38 ±0.37[b]	2.16 ± 0.25[b]	2.49 ± 0.25[b]	5.89 ±0.47[a]	130.39 ± 3.25[b]
RChP30%	54.70 ± 0.25[a]	2.86 ±0.11[a]	3.71 ±0.11[a]	6.32 ± 0.54[a]	137.08 ±2.21[a]
RLP 15%	51.62 ± 0.54[c]	2.20 ±0.0.44[b]	2.45 ± 0.26[b]	5.77 ±0.36[a]	128.49 ±2.11[bc]
RLP 30%	54.03 ±0.37[ab]	2.82 ± 0.34[a]	3.59 ±0.37[a]	6.23 ±0.37[a]	135.07 ±3.16[ab]

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same column are significant at $p \leq 0.05$.

3.5.2. Extensograph

The purpose of using the extensograph device is to determine the resistance and extension ability of the dough using the dough values (extensibility, relative resistance to extension, and energy). Table (9) shows the results of the extensograph parameters of MF, RChP, and RLP. The energy values explain the area below the curve and provide essential information about the dough's fermentation and the degree of workability. The result obtained that energy values ranged from 96.98 cm^2 to 92.68 cm^2 for all composite flours, where MF recorded the lowest value (70.48 cm^2**)**. The higher value in the long curve refers to good gas retention and good fermentation of the dough **(Hussin *et al*., 2022).** The parameters used to assess the capacity for processing of flour for various products and the baking qualities of flour are extensibility and the extension resistance, the high extensibility value indicated to better gas holding capacity and fermentation tolerances of the dough **(Aydoğan *et al*., 2013*)*.**

Increasing the amount of maize flour in dough caused it to lose its strength and extension properties and become weak and wasteful **(Abo Raya *et al*., 2022).** Results observed that incorporating RChP and RLP to MF dough increased the extensibility from 112.35 mm to (147.00,150.68, 151.51 and 152.88mm) respectly for dough contained (RLP 15%, RChP15%, RLP 30%, and RChP30%) respectively. The addition of RChP and RLP to MF showed markedly increasing resistance to extension. Our results are in the same line with **Bojňanská *et al*., (2021)** who indecated that the inclusion of legume flours mostly altered dough behaviour during the cooling phase, and there was an increase in resistance in all samples with a higher amount of legume Powder.

Table (9): Extensograph parameters of MF fortified with RChP and RLP

Parameters	**Energy (cm^2)**	**Extensibility (min)**	**Elasticity (B.U)**	**Proportiona number**
Samples				
MF100%	70.48±1.43^{c}	112.35±2.37^{b}	344.71±5.24^{c}	1.72±0.21^{b}
RChP15%	95.00±2.11^{ab}	150.68±3.43^{a}	464.14±5.43^{a}	2.35± 0.25^{a}
RChP30%	96.98±2.37^{a}	152.88±3.24^{a}	469.74±5.24^{a}	2.40±0.22^{a}
RLP 15%	92.68±2.21b^{b}	147.00±2.25^{ab}	446.50±4.43^{b}	2.29±0.19^{a}
RLP 30%	95.52±2.44^{ab}	151.51± 0.76^{ab}	462.69± 5.54^{a}	2.42±0.17^{a}

Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same column are significant at p≤0.05.

3.6. Sensory evaluation

3.6.1 Sensory evaluation of biscuit

Sensory features play an important part in adopting or rejecting different products and obtaining satisfaction from how they are used. In this study, color, odor, taste, and general acceptability were employed to assess sensory evaluation **(Varedesara *et al*., 2021).** Table (10) displays the sensory assessment of biscuits made by combining RChP and RLP with MF. Color is a significant factor in food selection and acceptance; color samples produced with RLP 30% had a higher color value (8.5) when compared to ather samples.

Results indicated that there was a difference between MF sample with RChP and RLP samples. Biscuits fortified with 15% and 30% RChP had taste ratings of 7.6 and 7.2, respectively. While biscuits fortified with RLP 15% and 30% had the highest values of taste (8 and 8.5, respectively).

Texture is a basic acceptability element of foods (**Muhimbula *et al*., 2011)**; biscuits prepared by adding 15% and 30% RLP were more accebtable than biscuits prepared by RChP 15%, while biscuits prepared by RLP 30% recorded the lowest score. Biscuits fortified with RChP 30% recorded the lowest value 7.6 for odor, while RLP 30% recorded the highest score 8.8. The addition of 15% and 30% RLP to MF led to an increase in overall acceptability compared to the rest of the samples, this result is accordance with **Grah *et al*., (2014)** and **Saleem *et al*., (2019)** who stated that adding lentil seed flour to wheat flour in different levels leads to improve the organoleptic (taste, aroma, and acceptability) quality of biscuits. And our results were nearly with results obtain by **Makram *et al*., (2023)** who reported that sensory properties of fortified biscuits with different levels (10%–20%) of chickpea and lentil showed significant differences ($P \leq 0.05$) in shape. **Abd Rabou, (2017**) and **Bijlwan *et al*., (2019)** indicated that chickpea products had the best flavour, crispiness, and acceptability. On the other side, our results are far from a study of **Abd Elnaby and Gouda, (2023)** who reported that Chickpea biscuit showed overall acceptability (4.88).

Table (10) Sensory evaluation of biscuit samples

Sensory Properties / Samples	Color	Taste	Texture	Odor	Overall acceptability
MF 100%	8.8 ± 0.56 ^{a}	8.3 ±0.8 ^{a}	7.9± 0.75^{ab}	8.1± 0.43^{a}	8.7 ± 0.75^{a}
RChP15%	7.8± 0.59 ^{b}	7.6± 0.98 ^{b}	7.4±0.77^{b}	8.0±0.80^{a}	7.7±0.77^{b}
RChP30%	7.5 ± 0.48 ^{b}	7.2±0.96 ^{b}	7.1±0.86^{b}	7.6± 0.59^{b}	7.2±0.86^{b}
RLP15%	8.0 ±0.83 ^{a}	8.5± 0.99 ^{a}	8.1± 0.63^{a}	8.8 ± 0.62^{a}	8.3± 0.63^{a}
RLP 30%	8.5± 0.87 ^{a}	8.0± 1.09 ^{a}	8.1± 0.97^{a}	8.8± 0.92^{a}	8.3± 0.97^{a}

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same column are significant at $p \leq 0.05$.

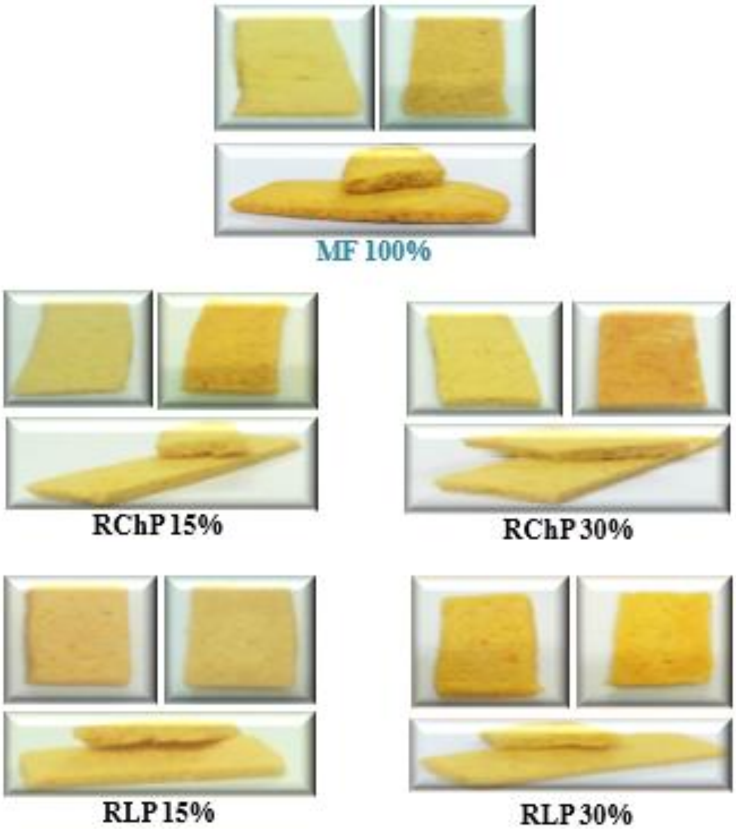


Photo (1): Biscuit samples

3.6.2 Sensory evaluation of crackers

Table (11) presents the sensory properties of crackers. MF was acceptable for all mesures test. The addition of chickpea and lentil to maize flour led to enhances of color and taste of the crackers. Color is a vital component of food selection and acceptance; crackers with RLP 15% had the highest color value 8.0 compared with crackers with RChP 15%, RChP 30%, and RLP 30%, which had a lower score 7.9, 7.1, and 6.5, respectively, which was significantly different from controls (9.9).

Taste is an important factor for sensory evaluations; there was a significant difference between MF and other samples; samples RLP (15% and 30%) had a taste value of 8.1, while samples RChP (15% and 30%) had the lowest 8.0 and 7.0 %, respectively. The sample RLP (15%) recorded a better score for odor and texture compared to other samples.

Our results, nearly to **El-Hadidy *et al*. (2022) and Yaver, (2022)** who revealed that using lentil flour at all addition levels elicited a lighter color, appearance, odor, crispiness, and overall acceptability, which may be due to the darker colour and higher density of lentil flour **Santos and Vasconcelos, (2023**).

Table (11) Sensory evaluation of crackers samples

Sensory properties / Samples	Color	Taste	Texture	Odor	Overall acceptability
MF100%	9.9±0.98 a	9.7±0.86 a	9.8 ±0.69a	9.9 ±0.50a	9.9 ± 0.44a
RChP15%	7.9 ±0.85b	8.0±0.86 b	7.8 ±0.73bc	8.1 ±1.04 b	7.5 ± 0.44 b
RChP30%	7.1±0.71 bc	7.0±0.68c	6.9 ± 0.49c	8.1± 0.50b	6.5 ± 0.40c
RLP 15%	8.0 ±0.92b	8.1± 0.57b	8.5 ±0.94b	8.3±0.38 b	7.8 ± 0.50b
RLP 30%	6.5 ±1.34C	8.1 ±0.99b	8.3± 0.97b	8.0± 0.92b	7.9 ±0.67b

RChP 15% = (MF 85% + RChP 15%). RChP 30%= (MF 70% + RChP 30%).
RLP 15%= (MF 85% + RLP 15%). RLP 30%= (MF 70% + RLP 30%).
Values of three independent repeats (n=3) are expressed as the mean ± SD.
Values with different letters in the same column are significant at p≤0.05.

Crackers containing 30% chickpea flour had the highest sensory attributes and contained high nutritional value (protein and fiber) (**Fatima *et al*., 2021**). The addition of RChP to foods such as bakery products could improve their nutritional value **(Large, 2021**). **Asker and Mousa, (2021)** found that fortifying noodles with 30% chickpea flour enhanced the texture of the dough; this could be due to the high content of protein in chickpea flour. In general, sensory qualities, including color, flavour, and taste ratings, could be the reason for the acceptable overall acceptability; however, the addition of legumes powder also raised the viscosity, volume, and texture of the bakery products **(Schmidt and Oliveira, 2023).**

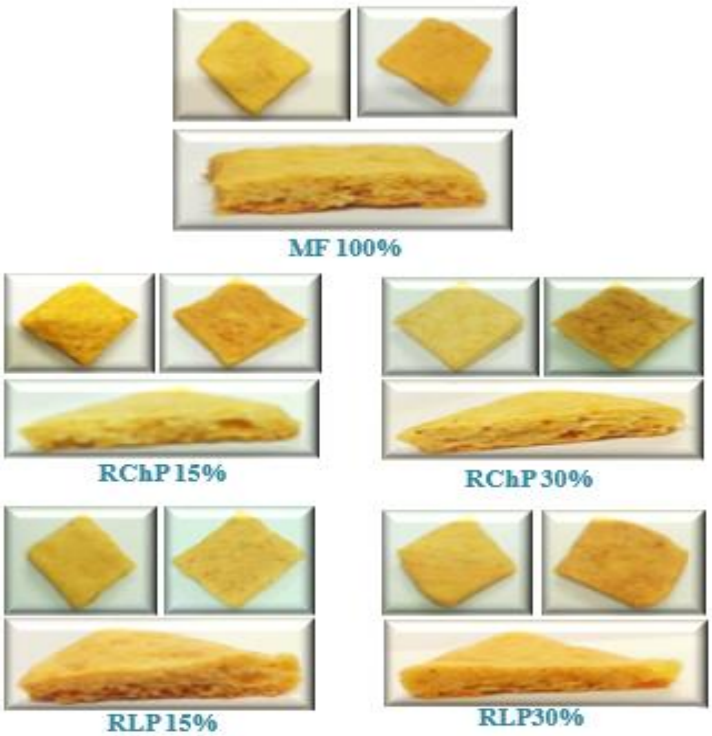


Photo (2): Cracker samples

Conclusion

Maize flour is widely used for all bakery products. The incorporation of maize flour with common legume powders (roasted chickpea and red lentil) at levels of 15% and 30% in biscuits and crackers could positively impact the increase in sources of protein and some minerals that improve the nutritional value of biscuits and crackers. Results found that the appropriate blend enhanced and influenced the dough's rheology, such as extensibility and elasticity, and subsequently their baking characteristics. Also, the properties of the final products (biscuits and crackers) were satisfactory and highly rated in color, taste, texture, and overall acceptance. So, this study recommends incorporating roasted chickpea and red lentil powders with maize flour to improve the nutritional quality, sensory, and functional properties of bakery products.

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تطوير الخصائص الوظيفية والريولوجية لمنتجات المخابز من دقيق الذرة ومساحيق العدس والحمص

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الملخص

تعتبر الذرة من أهم المحاصيل الإستراتيجية في مصر وتأتي في المرتبة الثانية بعد القمح، وتستخدم على نطاق واسع لإنتاج الخبز والوجبات الخفيفة. لذا، يهدف هذا العمل إلى تدعيم دقيق الذرة بمسحوق البقوليات (الحمص المحمص والعدس الأحمر) لتعزيز قيمته الغذائية. ودراسة تأثير دمج 15و 30% منهم على الخصائص الكيميائية والوظيفية والريولوجية للعجين. كما أن التقييم الحسي للمنتج النهائي (البسكويت والمقرمشات) سيكون ضمن نطاق هذا البحث. أشارت النتائج إلى أن دقيق الذرة يحتوي على نسبة أعلى من محتوى الكربوهيدرات والرطوبة والألياف (71.95، 10.55، و3.15٪، على التوالي) من مسحوق الحمص والعدس الأحمر. من ناحية أخرى، سجلت البقوليات (الحمص والعدس) أعلى نسبة بروتين($p \leq 0.05$) معنوياً (23.95 و21.85 على التوالي) مقارنة بدقيق الذرة (9.15%). البقوليات مصادر مناسبة لـ بوتاسيوم ، كالسيوم ، الفسفور والحديد . يحتوي مسحوق الحمص علي محتويات عالية تبلغ 885 و151 و382 و9.3 ملجم/ 100جم للبوتاسيوم ، كالسيوم ، الفسفور والحديد على التوالي. فيما يتعلق بجهاز الفارينوجراف، كان أعلى زمن تطوير وزمن استقرار 3.71 و6.32 دقيقة على التوالي، بالنسبة لمسحوق الحمص 30%؛ وكانت أدنى القيم 2.5 و3.71 دقيقة، على التوالي، بالنسبة لدقيق الذرة. ولوحظ أيضًا أن دمج مسحوق الحمص والعدس بنسبة 15% و30% في العجين أدى إلى زيادة قابلية التمدد من 112.35 ملم للعينة الضابطة إلى 150.68 و152.88 للعجين المحتوي على 15% و30% من مسحوق الحمص على التوالي و147.00 و151.51 ملم للعجين المحتوي على 15%. 30% من مسحوق العدس على التوالي. في الختام، تشير النتائج إلى أنه من خلال خلط مسحوق الحمص المحمص ومسحوق العدس الأحمر مع دقيق الذرة، من الممكن تعزيز القيمة الغذائية (البروتين والمعادن) والخصائص الوظيفية للبسكويت والمقرمشات والمحافظة على خصائصها الحسية.

الكلمات المفتاحية: البقوليات، دقيق الذرة، القيمة الغذائية، الخصائص الحسية، الدقيق المركب، الخصائص الفيزيائية والكيميائية.