



Production of Iraqi bread by replacing wheat flour with chickpea flour and its effect on rheological and sensory properties

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ABSTRACT

Background: Weak flour is one of the undesirable factors in determining the suitability of wheat flour for bread making; therefore, various additives are used to improve the properties, stability, and strength of the dough.

Objective: Iraqi bread has been produced and enriched with chickpea flour, which helps in some cases of intestinal disorders and gluten sensitivity. The aim of this study was to determine the quality and consumer acceptance of the final product prepared with different substitution ratios. Two types of bread were produced: pure wheat bread without additives (T1 treatment) and wheat bread enriched with chickpea flour, at rates of 15%, 30%, and 45% (T2, T3, and T4 treatments, respectively).

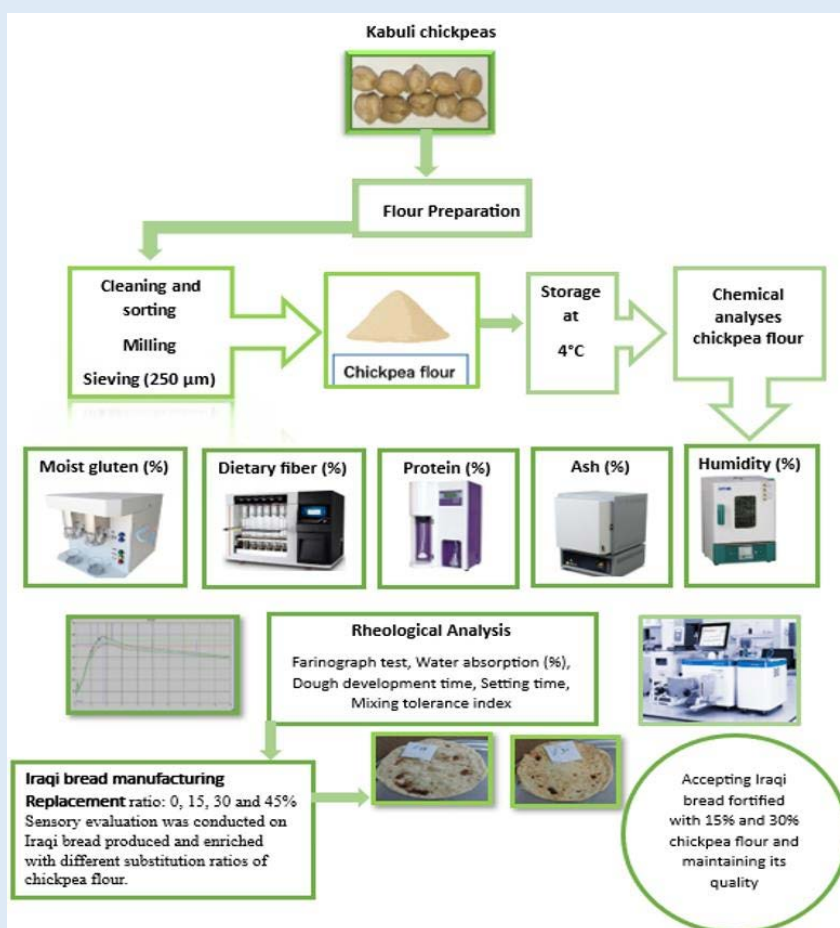
Results: The results showed that chickpea flour significantly affected most quality indicators. The chemical analysis showed that increases in protein and ash percentages in T4 amounted to 14.45% and 3.93%, respectively. Treatment T1 was characterized by high levels of moisture, wet gluten, and dry gluten amounted to 14.07%, 33.51% and 11.18%, respectively. Concerning rheological tests of the treatments under study, it was shown that T1 was superior to other treatments with an average of (71.70%), while T4 achieved the lowest value of (64.70%) in water absorbency. For arrival

time in farinograph results, T1 recorded the highest value amounted to (2.61 minutes), While T4 recorded the lowest value (2.08 minutes).

Novelty: This research showed that using some natural ingredients such as protein-rich chickpea flour with wheat flour improves the texture of the dough. The addition of chickpea flour improves the quality and nutritional value of wheat flour. Chickpea flour can be used as a substitute to improve dough properties. Use of composite flour technology will contribute to reducing food insecurity because chickpeas are cheap and widely available in our country.

Conclusion: From this study, it can be concluded that wheat bread enriched with chickpea flour produced good quality products. According to the above, it is recommended to add chickpea flour at a rate between 15% and 30% to enhance nutritional value in bread without impact on its sensory qualities.

Keywords: Iraqi bread, chickpea flour, rheological properties, Enhancing nutritional value.



Graphical Abstract: Iraqi bread production using wheat flour partially substituted with chickpea flour and study its properties

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INTRODUCTION

In the human diet, wheat occupies the leading position among cereal crops. This is due to the low cost and easy availability of its products that makes wheat flour a staple ingredient in many daily diets. Iraqi Bread is an important staple food product and is prepared by baking dough prepared from refined wheat flour, water and other ingredients. When wheat is refined into flour, most of the bran and wheat germ are partially or completely removed. They are the main source of nutrients, and therefore, bread made from refined wheat flour has a low nutritional value [1]. Gluten is the main ingredient that gives dough its elasticity and ability to retain gas produced by fermentation. This contributes to the rise of the dough and the quality of the final bread. Glutenin protein is characterized by its high viscosity and low elasticity, while gliadin is known for its high elasticity, but low viscosity. The balance of these qualities is essential for producing better quality baked products [2]. Despite the technological importance of gluten in the bakery industry, it is the main culprit in the emergence of celiac disease, which is a chronic immune disorder triggered by gluten consumption in people who suffer from it. Therefore, a low- or gluten-free diet is the only treatment currently available for this group of patients. Accordingly, significant scientific efforts are being made to develop gluten-free baked products using suitable alternatives to conventional flour [3]. This study corresponds primarily to Steps 4 and 6 of the Functional Food Center's 17-step model. It focuses on the identification of bioactive compounds and the development of a functional food prototype with demonstrated antimicrobial and sensory properties. Many researchers demonstrated that wheat proteins activate immune cells in the stomach and other tissues, causing an increase in inflammatory symptoms [4,5]. A study conducted by researchers [5] indicated the importance of improving bread quality by adding

nutrient-rich ingredients such as legume seed flour to develop nutrient-rich breads and biscuits. Chickpeas (*Cicer arietinum L.*) are a globally valuable legume, known for its health benefits, nutritional value and affordable prices. It is rich in vitamins, fiber, protein, minerals such as magnesium, iron, folic acid, and zinc. Chickpea flour is a promising alternative to wheat flour, as it has a good and rich taste, in addition to its high content of proteins and dietary fiber. However, replacing wheat flour with chickpea flour may lead to changes in the structure of the gluten and starch, which requires the addition of improvers, enzymes, and hydrocolloids to improve the properties of the dough in terms of water absorption and gas retention [6]. Enhancing the role of chickpeas as a nutritional ingredient through effective treatment methods can greatly reduce potential negative effects associated with antinutrients, such as phytates, enzyme inhibitors, and lectins found in chickpeas[7].

MATERIALS AND METHODS

Flour preparation: Sham 6 wheat was obtained from the Seed Certification Department, Ministry of Agriculture, Baghdad. Grains were moistened by adding water in measured quantities to bring the moisture content to 14% and was left for 24 hours to hydrate. The grains were then grounded, placed in a sealed bag, and kept in the refrigerator until tests were done. As for chickpea flour, large chickpeas of Kabuli variety were obtained from local markets, cleaned of impurities, washed with water several times, then dried and ground in an electric mill according to the method of [8]. Chickpea flour was sifted using a 0.4 mm sieve and kept in sealed bags until use.

Chemical analysis: This moisture content of flour was measured using a PFEUFR-HE-50 moisture tester (OZEN, Germany) using standard method No. (0.8-0.1). The ash contents of wheat flour and chickpea flour were estimated using the method described by [9]. The

percentage of protein was estimated using an Inframatic device (Perten, Sweden) according to the standard method of [10]. The fat content of the samples was estimated as described in [11]. Total carbohydrates were estimated by the arithmetic difference method [12] and the percentage of fiber was estimated according to the method described by [11]. The wet gluten content of wheat flour and chickpea flour was estimated using the standard method of [9] by using the Glutomatic gluten index device (Perten, Sweden). All chemical analyses (moisture, ash, protein, fat, fiber, and carbohydrate) were performed in three laboratory replicates for each flour formulation. Results were expressed as the mean.

Rheological analyses

Farinograph examination: The mixing properties of dough for different replacement ratios of wheat and chickpea flour were studied using a Brabender farinograph according to the method [9]. A 300 g mixing bowl was used in the farinograph, and the following results were obtained: water absorption of flour, time to reach texture, dough maturation time, stability, and departure time. Farinograph measurements were carried out in three independent runs for each flour blend (T1–

T4), using freshly prepared composite flour samples. The reported farinograph parameters represent the mean values.

Iraqi bread manufacturing: The traditional home method was adopted to make the local Iraqi bread using the direct mixing and baking method according to what was mentioned in [13]. The dough was prepared from standard ingredients (Table 1) with the addition of a certain amount of water, determined based on farinograph readings for each treatment. This is to ensure a homogeneous dough. The process of mixing the ingredients together was carried out by hand until it reaches the point of maturity. Fermentation was done at 30-35°C for two and a half hours. The dough was cut into equal pieces, baked in the oven, and subsequent sensory evaluations were carried out. Bread production for each formulation (T1–T4) was carried out in three independent technological replicates, prepared on the same day using the same raw materials and equipment. Each replicate consisted of three dough pieces (loaves) per treatment. The final dough mass for each loaf was about 145 g.

Table 1: Ingredients of the Iraqi bread dough made from wheat flour with different proportions of chickpea flour.

Treatment	Replacement ratio	wheat flour (g)	chickpea flour (g)	Yeasts* (g)	Salt (g)	Sugar (g)
T1	0%	1000	0	15	10	5
T2	15%	850	150	15	10	5
T3	30%	700	300	15	10	5
T4	45%	650	450	15	10	5

* Yeast used was dry active yeast.

Sensory evaluation: Sensory evaluation was conducted on Iraqi bread produced from wheat enriched with chickpea flour at different substitution ratios and for

each technological replicate according to the form followed by [13]. A panel of ten trained assessors (mixed male and female), experienced in the evaluation of

cereal-based products, participated in the analysis. Bread samples were coded with random three-digit numbers, and they were presented in a randomized order to minimize bias. Panelists evaluated key sensory attributes (e.g., appearance, texture, flavor, and overall acceptability).

Statistical Analysis: The experimental design followed a completely randomized design (CRD). Data were analyzed by analysis of variance (ANOVA) using the General Linear Model (GLM) procedure in SAS (version 9.0, SAS Institute Inc., Cary, NC, USA) to evaluate the

effect of chickpea substitution level on all measured variables [14, 15]. Treatment means were compared using Duncan's multiple range test when the ANOVA indicated significant differences at a probability level of $\alpha = 0.05$. All results are reported as the mean based on three independent observations (replicates).

RESULTS AND DISCUSSIONS

The percentages of chemical composition for wheat flour and chickpea flour were examined, and the results were shown in Figure 1.

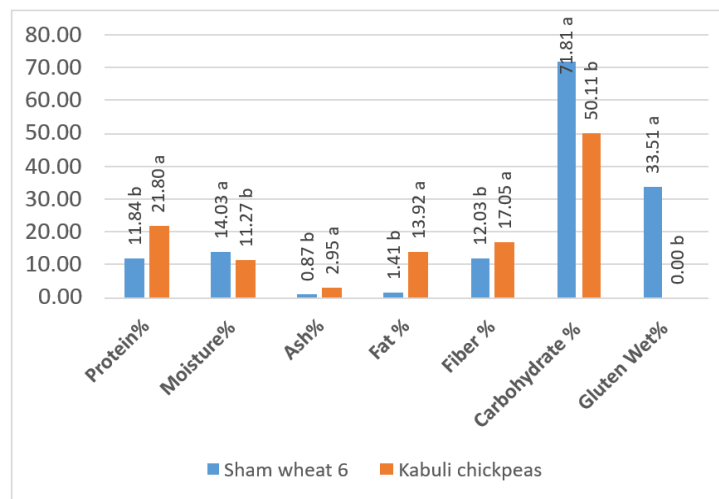


Figure 1: Chemical composition of wheat and chickpea flour

The protein content of grains is a qualitative trait that is strongly influenced by environmental conditions. It is also considered one of the fundamental standards for wheat quality, which depends mainly on genetic factors specific to the variety, type, and environmental conditions. The results indicate that chickpea flour has a high protein content of 21.8% compared with the protein content of Sham 6 wheat flour which reached 11.84%. Moisture content is one of

the most important factors in maintaining the stability of grains during storage. The highest percentage of moisture was recorded in wheat flour (14.0%), while it was 11.27% in chickpea flour. Concerning ash, fat and fiber, the highest levels were recorded in chickpeas compared to wheat. They reached 2.95%, 13.92%, and 17.05%, respectively. For carbohydrates and wet gluten, wheat recorded the highest values, reached 71.81% and 33.51%, respectively.

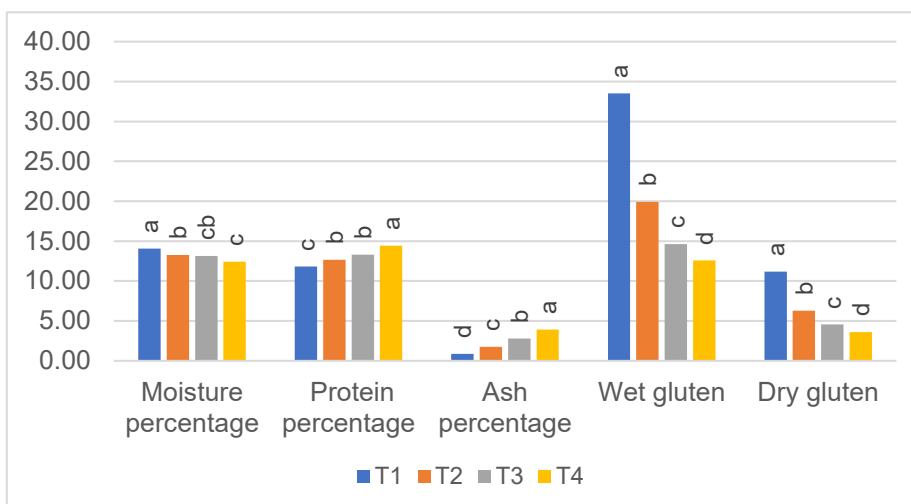


Figure 2: Chemical composition of the flour of the studied treatments

The results shown in Figure 2 indicate that the moisture content in wheat flour in the control (T1) reached 14.07%, while it decreased in all other treatments and was at its lowest value in T4 (12.43%). The reason for the decrease in moisture may be attributed to chickpea flour addition, which gradually reduced the moisture content with an increased percentage of replacement and fortification. Treatment T4 outperformed in the protein percentage with its highest value of 14.45%, While T1 showed the lowest value of 11.84%. The reason for this superiority of the T4 treatment is the high protein content of chickpea flour. This is the case with most legume flours. The extraction rate of the flour plays a major role in determining the ash content. In any case, the ash contents of the flour of all treatments were within acceptable limits. Treatment T4 gave the highest ash content of 3.93%, while T1 gave the lowest value of 0.87%. The reason for superiority of the T4 sample is that the chickpea flour contains a higher percentage of minerals and fiber, which affects the ash content of the compound flour. A high percentage of wet gluten gives a good indicator of favorable rheological properties of the dough. The highest percentage of wet gluten was recorded in treatment T1, which reached

33.51%. Good gluten is characterized by its high ductility and water absorption compared to weak gluten. In this study, the T4 sample gave the lowest value for these traits, reaching 12.59%. This may be due to the T4 sample giving the lowest percentage of gluten, while having a higher percentage of protein. The addition of chickpea flour leads to an increase in non-gluten proteins, which is beneficial in reducing the harmful effects of gluten for those with wheat allergies. If the gluten network is weak or its concentration is low, this may lead to reducing the size of the pores within the dough, which negatively affects heat transfer and biochemical reactions during baking, including the starch gelatinization process and dough cohesion as confirmed by [16]. After drying wet gluten at 100°C for 24 hours, dry or moisture-free gluten was obtained. Despite the close relationship between wet and dry gluten, it may not be possible to find consistency between them, which is mainly due to the difference in the amount of moisture retained by gluten. Therefore, calculating the dry gluten ratio will be important to determine the moisture ratio that is absorbed by different gluten parameters when water is added to it. The control sample, as shown in Figure 2, recorded the highest percentage of 11.18%,

while the T4 sample gave the lowest value of 3.60%. The reason for the superiority of the control in the percentage of dry gluten was because of its superiority in the percentage of wet gluten, due to the direct relationship between them. The results were consistent with [17], who noted that this bread has a specific size on top, resembles a loaf of wheat bread, has softer crumb, improved color, better crumb porosity, higher moisture content, less water loss, and good sensory properties.

Rheological properties: Farinograph measurements:

Flour water absorption: It is the amount of water required at 30°C to bring the mature dough to the 500 Brabender unit's line. Water absorption values are

affected by extraction rates, gluten content, and the presence of damaged starch and pentosan. Fine size of flour grains is preferred as flour that can absorb water is preferred [18]. This property is important because it leads to an increase in the amount of production during the bread manufacturing process. The results in Table 2 showed that the control sample outperformed the rest of the samples with an average of 71.70%, while the T4 sample achieved the lowest value of 64.70%. The reason may be attributed to the high percentage of gluten, which works on an increase in water absorption rate due to the interaction of fibers with gluten, which affects the dough mixing properties [19]

Table 2: Rheological analyses (farinograph values) for wheat flour and chickpea flour blends.

Treatment	Water absorption of flour	Time to reach texture	Dough maturation time	Stability	Departure time
T1	71.70	2.61	4.31	5.22	7.85
T2	68.52	2.32	4.14	3.81	6.14
T3	66.03	2.15	3.60	2.06	4.12
T4	64.70	2.08	3.42	1.61	3.63

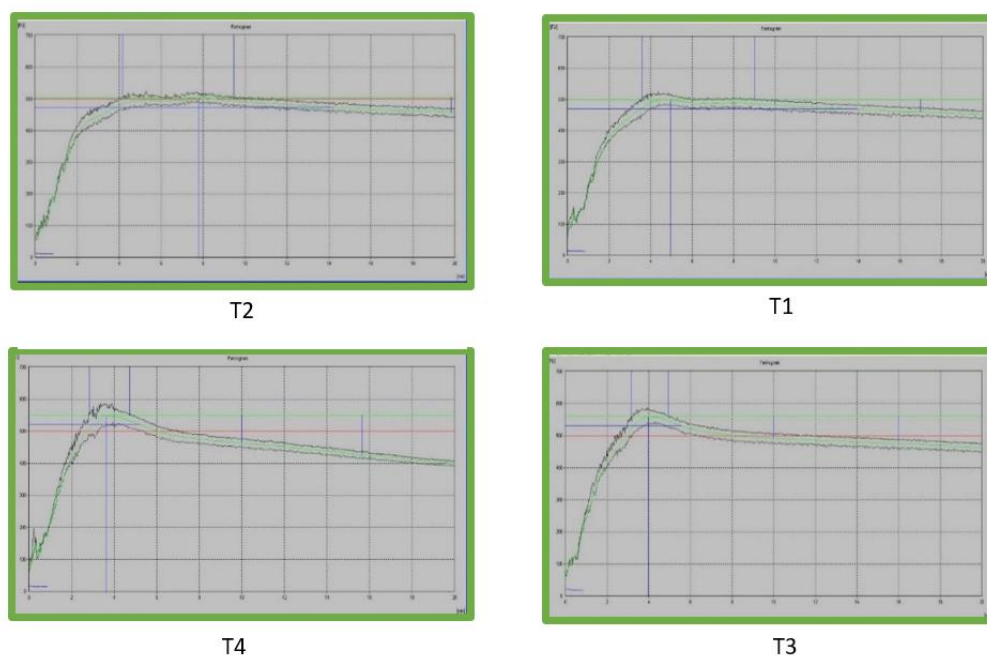


Figure 3. Farinograms curves of wheat flour and chickpea flour blends at different substitution levels (T1-T4).



Image 1: Dough made with wheat flour substituted with chickpea flour at 0, 15, 30, and 45%.

2- Arrival time (min): The time that starts from the moment of water addition and turning the device on until the curve reaches the 500 Brabender unit line when the gluten network is completed. The results in Table 2 indicate that the control sample gave the highest average for this trait, reaching 2.61 minutes, while treatment T4 gave the lowest average for this trait, reaching 2.08 minutes. The arrival time has been significantly affected due to the legume flour substitution, as it does not contain gluten capable of forming a cohesive dough, and thus the dough structure is affected, as researchers have noted that a 15-30% substitution contributes to a deterioration in access time as the substitution ratio increases [20].

3- Maturation time: The time required for the curve to reach its highest peak since adding water and turning on the device. The results in Table 2 showed that T1 was superior, as it recorded the highest value for the trait reaching 4.31 minutes, while T4 achieved the lowest maturation time value of 3.42 minutes. The replacement of wheat flour may affect the gluten network because chickpea flour contains a high percentage of fiber and is also considered to be a gluten-free type of flour, which contributes to shortening the dough's ripening time.

When the replacement ratio rises to more than 7.5%, it gives a shorter maturity time than the control treatment [21].

4- Stability period (minutes): The stability period is an important characteristic because it determines the quality of flour and the pressure it can withstand during the bread manufacturing stages. The results in Table (2) showed that T1 was superior and gave the highest value for the stability period of 5.22 minutes, while T4 achieved the lowest stability period value of only 1.61 minutes.

5- Departure time (min): The time calculated from the addition of water and turning on the device until the curve leaves the 500 Brabender line. It is equal to the sum of the stability time and the arrival time. The results in Table (2) showed that the longest recorded time to departure was for T1, 7.85 minutes, while T4 achieved the lowest recorded departure time, which was 3.63 minutes. Adding different proportions of chickpea flour greatly affects the water absorption of the dough. Although it contains fiber, it absorbs less water. Therefore, the dough needs special care as the percentage of substitution increases [22] as shown in image 1.

The results shown in Figure 3 demonstrated that there are no significant differences between the treatments in the characteristics of bread surface color. The products of the control sample (T1) and other treatments T2, T3 and T4 were different from each other, and the highest value was for T2 which reached 19.00 and the least significant difference was in T4 which reached 17.25. As for the back color trait, the largest statistically significant value was for T2, reaching 9.50, and the lowest

significant value was for T4, reaching 8.25. The elasticity and chewability properties were significantly higher in treatments T2 and T3, reaching 8.75, while this value was less significant in T4, which reached 7.50. For odor, the highest value was in T2, reaching 18.00, and the least noticeable difference was in T4, as it reached 15.25. The taste and regularity of shape had the highest noticeable difference in T2, as it reached 18.75, while it decreased in T4, reaching 14.25.

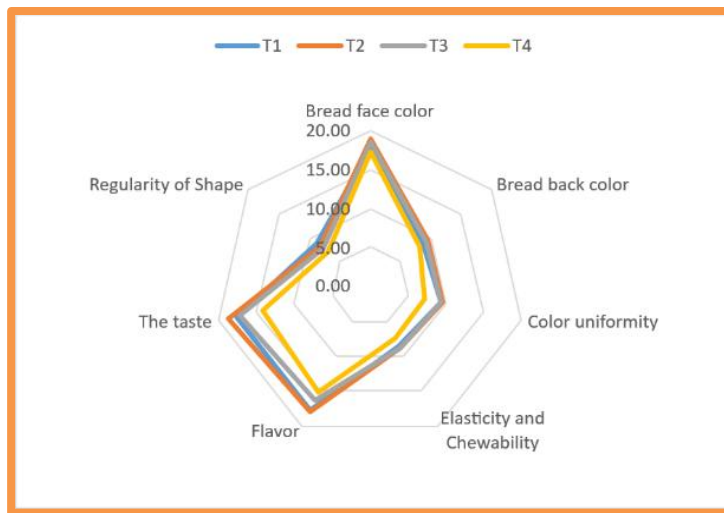


Figure 3: Sensory assessment of Iraqi bread fortified with various replacement ratios of chickpea flour

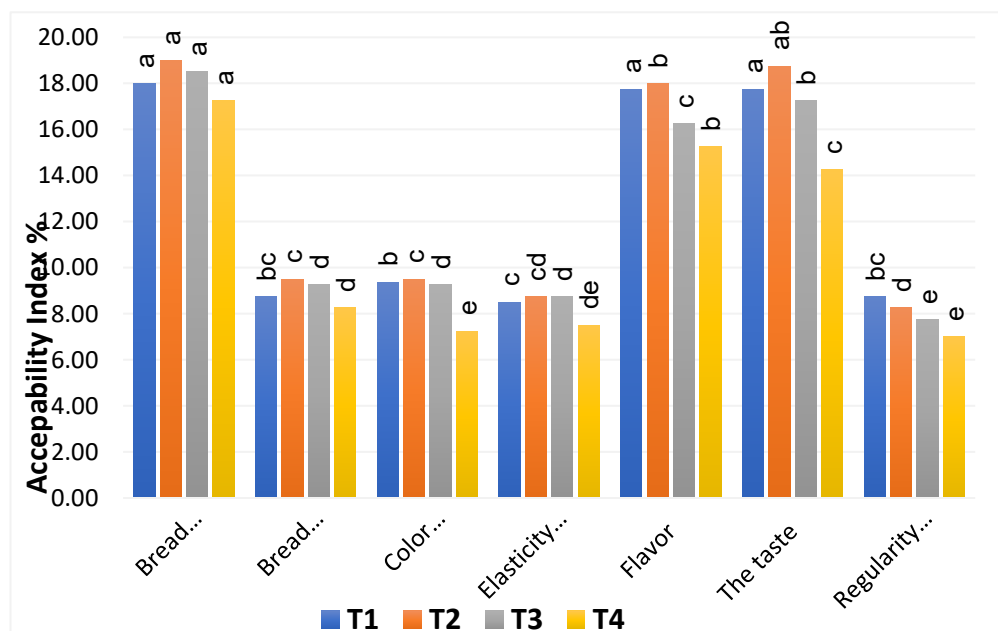


Figure 4: Sensory assessment of Iraqi bread fortified with various replacement ratios of chickpea flour

The decrease in taste and smell at high substitution levels of legume flour is due to the natural taste and smell of legumes, which is considered a disadvantage of adding legume flour to bread [23,25]. The regularity of shape was significantly higher in treatment T2 and reached 8.25, while treatment T4 recorded the lowest regularity of shape, which reached 7.00. When looking at the sum of these qualities, the highest significant difference in

treatment was observed in treatment T2 with a value of 91.75% compared to the rest of the treatments, and it was widely accepted by the arbitration committee [26,27]. The lowest significant difference was observed for the T4 treatment, reaching 76.75%. This is due to the formation of gluten networks in the bread dough, which are characterized by flexibility, elasticity, and the ability to swell [28-29]. The results were consistent with [17,30].



Image 2: Iraqi bread made from wheat flour substituted with chickpea flour at 0, 15, 30, and 45%

From a nutritional and health perspective, many studies indicate that products made from composite flour (wheat flour with chickpea flour) offer higher nutrition and health value compared to those made from low-extraction wheat flour alone. This improvement is a result of nutritional integration and the quality of essential amino acids among the components of the compound flour, and the high percentage of dietary fiber, vitamins and minerals in the flour of other cereal crops such as chickpea. The addition of chickpea flour reduces the viscosity of the batter during heat treatment, cooling, and cooking, which the properties differ due to its varying physical and chemical properties compared to wheat

flour [1], as shown in image 2.

CONCLUSION

Through this study, it can be concluded that using composite flour technology, which is considered beneficial in our country, will contribute to reducing the feeding gap. It also shows the possibility of using different crop flours partially as a substitute for wheat flour without adversely affecting the sensory properties while enhancing the nutritional and therapeutic value of baked products. There is a need to modify mixing and baking techniques to improve the quality of the produced Iraqi bread.

Authors Contribution: Noor Jumhaa Fadhil: Formal analysis; Methodology; Saad Ibrahim Yousif Project administration; Funding acquisition; Ghenea Hamid Abdulkreem Validation and Writing original draft. Sara Thamer Hadi :Data duration ;Formal analysis and Methodology .

Competing Interests: The authors declared no conflict of interest.

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REFERENCES

- Mesta-Corral M, Gómez-García R, Balagurusamy N, Torres-León C, and Hernández-Almanza AY. Technological and nutritional aspects of bread production: An overview of current status and future challenges. *Foods*. 2024;13:2062. DOI: <https://doi.org/10.3390/foods13132062>
- Ye L, Zheng W, Li X, Han W, Shen J, Lin Q, et al. The role of gluten in food products and dietary restriction: exploring the potential for restoring immune tolerance. *Foods*. 2023;12:4179. DOI: <https://doi.org/10.3390/foods12224179>.
- Massironi S, Franchina M, Elvevi A, Barisani D. Beyond the gluten-free diet: innovations in celiac disease therapeutics. *World Journal of Gastroenterology*. 2024; 30:4194-4210. DOI: <https://doi.org/10.3748/wjg.v30.i38.4194>.
- Konozy EH, Osman ME. From inflammation to immune regulation: the dual nature of dietary lectins in health and disease. *Heliyon*. 2024; 10:20. DOI: <https://doi.org/10.1016/j.heliyon.2024.e39471>
- Martirosyan DM, Stratton S. Quantum and Tempus theories of functional food science in practice. *Functional Food Science*.2023;3(5):55–62. DOI: <https://doi.org/10.31989/ffs.v3i5.1122>
- Gao Y, Hao X, Hu Y, Zhou N, Ma Q, Zou, et al. Modification of the functional properties of chickpea proteins by ultra-sonication treatment and alleviation of malnutrition in rat. *Food Function*. 2023; 4:1773–1784. DOI: <https://doi.org/10.1039/D2FO02492F>
- Kumar N, Hong S, Zhuo Y, Garay A, Yang J, Henderson D, et al. Comprehensive review of chickpea (*Cicer arietinum*): nutritional significance, health benefits, techno-functionalities, and food applications. *Comprehensive Reviews in Food Science and Food Safety*. 2025;24:e70152. DOI: <https://doi.org/10.1111/1541-4337.70152>.
- Singh R, Kumari P, Yadav B. Proximate composition analysis of cereal and legume flours: updated methods for carbohydrate by difference and dietary fiber determination. *Food Chemistry*. 2024; 425:137295. DOI: <https://doi.org/10.47739/2333-6706/1051>
- Singh P, Kaur M, Yadav RB. Physicochemical characterization of wheat and chickpea flour: moisture and ash determination using standard laboratory methods. *Journal of Cereal Science*. 2024; 115:105245. DOI: <https://doi.org/10.3390/foods9030280>
- Chadalavada K, Anbazhagan K, Ndour A, Choudhary S, Palmer W, Flynn JR, Mallayee S, Pothu S, Prasad KVS, Varijakshapanikar P, et al. NIR Instruments and Prediction Methods for Rapid Access to Grain Protein Content in Multiple Cereals. *Sensors*. 2022; 22(10):3710. DOI: <https://doi.org/10.3390/s22103710>
- Hadi ST, Fadhil NJ, Khalaf AS, Alhadithi HJ. Extraction of pectin from quince (*Cydonia Oblonga*) fruit husk and using it in jam industry. *Biochemical and Cellular Archives*.2020; 20, 2163-2166. DOI: <https://doi.org/10.35124/bca.2020.20.1.2163> .
- Begum N, Khan QU, Liu LG, LiW, Liu D, Haq, et al. Nutritional composition, health benefits and bio-active compounds of chickpea (*Cicerarietinum*L.) *Frontiers in Nutrition*. 2023; 10:1218468. Doi: <https://doi.org/10.3389/fnut.2023.1218468>
- Parmigiani M, López DN, Llopart EE, Boeris V. Sensory evaluation of wheat bread supplemented with chickpea: the effect of the chickpea flour fermentation. *Food and Humanity*. 2025;4:100527. DOI: <https://doi.org/10.1016/j.fooHum.2025.100527>
- Halil M R. Adding yellow corn flour and triticale to bread mix. Master's thesis 1983. College of Agriculture, University of Baghdad. Mwalugha HM, Molnár K, Rác C, Kovács S, Adácsi C, Dövényi-Nagy T, et al. Irrigation, nitrogen supplementation, and climatic conditions affect resistance

- to *Aspergillus flavus* stress in maize. *Agriculture*. 2025;15(7):767.
DOI: <https://doi.org/10.3390/agriculture15070767>.
15. Nkurikiye E, Chen G, Tilley M, Wu X, Zhang G, Fritz A, et al. Incorporating chickpea flour can enhance mixing tolerance and dough strength of wheat flour. *Cereal Chemistry*. 2023;100:1250-1262.
DOI: <https://doi.org/10.1002/cche.10705>
 16. Imam YT, Ironi EA, Awoyale W, Ajani EO, Alamu EO. Application of legumes in the formulation of gluten-free foods: functional, nutritional and nutraceutical importance. *Front Sustain Food Syst*. 2024;8:1251760.
DOI: <https://doi.org/10.3389/fsufs.2024.1251760> .
 17. Teobaldi AG, Carrillo Parra EJ, Barrera GN, Ribotta PD. The Properties of Damaged Starch Granules: The Relationship Between Granule Structure and Water–Starch Polymer Interactions. *Foods*. 2025; 14(1):21.
DOI: <https://doi.org/10.3390/foods14010021>
 18. Burešová I, Lullien-Pellerin V, Červenka L, Mlček J, Šebestíková R, Masaříková, L. The comparison of the effect of flour particle size and content of damaged starch on rice and buckwheat slurry, dough, and bread characteristics. *Foods*. 2023; 12:2604.
DOI: <https://doi.org/10.3390/foods12132604>
 19. Atudorei D, Mironeasa S, Codină GG. Dough rheological behavior and bread quality as affected by addition of soybean flour in a germinated form. *Foods*. 2023; 12:1316.
DOI: <https://doi.org/10.3390/foods12061316>.
 20. Danial N, Mousavi SA. Optimization, modeling, and characterization of water treatment sludge modified by ultrasound-assisted acid activation for enhancing turbidity removal. *Environment, Development, and Sustainability*. 2021; 23: 8377-8393.
DOI: <https://doi.org/10.1007/s10668-020-00971-z>
 21. Arendt EK, Zannini E. Cereal grains for the food and beverage industries. Oxford: Elsevier; 2013.
DOI: <https://doi.org/10.1533/9780857098924>.
 22. Kotsiou K, Palassaros G, Irakli M, Biliaderis CG, Lazaridou A. Effect of pretreated yellow split pea flour supplementation on dough rheology, texture, volatile profile, and sensory attributes of wheat flour–based breads. *Food Bioprocess Technol*. 2025;18(4):3993–4009.
DOI: <https://doi.org/10.1007/s11947-024-03703-7>.
 22. Hedao R, Chatterjee S, Singh A, Patil M. Formulation and evaluation of a spirulina-enriched popsicle using indigenous Indian blackberry: nutrient density and seed waste valorisation. *Functional Food Science*. 2025;5:567–583.
DOI: <https://doi.org/10.31989/ffs.v5i11.1795>
 23. Fadhil NJ, Almairza BA, Majeed A, Hadi ST. Manufacturing functional biscuits fortified with dill (*Anethum graveolens* L.) and assessing its physical and sensory properties and microbial activity. *Bioactive Compounds in Health and Disease*. 2026;9(1):1–12.
DOI: <https://doi.org/10.31989/bchd.9i1.1871>
 24. Al-Alwani HIS, Fadhil NJ, Yousif SI. Study the impact of replacing peanut flour with wheat flour on physicochemical properties and sensory assessment of biscuits produced. In: IOP Conference Series: Earth and Environmental Science. 2024;1158(11):112009.
 25. Al-Alwani HI, Fadhil NJ, Yousif SI. The effect of replacing wheat flour with sesame and flax flour on the chemical composition, fatty acids, and antioxidant properties of biscuits. *Tikrit Journal for Agricultural Sciences*. 2023;23(4):74-84.
DOI: <https://doi.org/10.25130/tjas.23.4.7>
 26. Al-Ameen MLK, Al-Azzawi FFH, Fadhil NJ. Effect of some medical plant extracts and chemicals on hormones of female rats. IOP Conference Series: Earth and Environmental Science. 2023;1252(1):012159.
DOI: <https://doi.org/10.1088/1755-1315/1252/1/012159>
 27. Sultan LJ, Fadhil WG, Hamid MM, Hadi ST. A comparative study of the effect of extracts extracted from *Ocimum basilicum* leaves using organic extract and essential oil. *Functional Foods in Health and Disease*. 2024;14(6):380–387. DOI: <https://doi.org/10.31989/ffhd.v14i6.1304>
 28. Ismael FN, Hadi ST. The effect of thyme, rosemary, and lemongrass oils on extension of the shelf life and qualitative characteristics of Iraqi soft cheese. *Functional Foods in Health and Disease*. 2024; 14(1):1-13.
DOI: <https://doi.org/10.31989/ffhd.v14i1.1262>