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Production and Quality Evaluation of Arabic Bread from Different Gluten-Free Flours

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ABSTRACT

This study aims to produce gluten-free flatbread for Celiac Disease (CD) patients from different gluten – free flour sources, at household or commercial level, and compare its quality with that produced from wheat flour. Arabic flat bread was prepared, using the straight dough method, from the whole grains, gluten- free, flours of corn, millet, buckwheat, quinoa, rice, potatoes, and tapioca. Straight grade wheat flour was used for comparison. The specific volume, pocket formation, upper to lower layer ratio and water activity of the obtained breads, as well as their tenderness immediately and 4 hours after baking, and taste were evaluated.

Proximate composition of the flours indicated that wheat flour had the highest protein content on wet basis (13.7%) seconded by, and significantly ($P \leq 0.05$) higher than, those of corn, millet, buckwheat, and quinoa (12.6 % - 12.0%). The flours of rice, and potatoes had medium levels (7.90 and 7.85%) but significantly ($P \leq 0.05$) higher than the protein content of tapioca flours (0.22%) which was the lowest. Sensory and physical evaluation of the bread types showed that most flour types gave bread loaves with good specific volumes compared to wheat flour. Most bread types were tender when freshly baked, but only wheat and potato breads maintained their tenderness 4 hours after baking. The taste of potato and tapioca breads were the most acceptable and similar ($P \leq 0.05$) to that of wheat bread followed by corn and rice breads. It can be concluded that flatbread with good and acceptable sensory and functional properties can be produced at household, and bakery levels without additives, with the simplest of tools and home appliances from most flours especially if consumed fresh after baking.

Keywords: Arabic bread, Bread quality, Gluten-free flours, Celiac disease

INTRODUCTION

Gluten is the main protein of the cereal grains of wheat, some oat varieties, barley, rye, and triticale. It makes up to 85% of the total wheat flour protein content (Lagrain et al.,2008) and is responsible for the viscosity and extensibility of the dough due to its content of alcohol-soluble prolamines (gliadins of wheat). Its acetic acid-soluble glutenin fraction is also responsible for the

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cohesiveness, strength, and elasticity conferred on the dough (Wieser,2007; Chen,2019). These properties combined, give the wheat flour dough its desirable rheological properties of extensibility and elasticity (Shewry,2009). In bakery products, gluten is responsible for water absorption during mixing and gas production and retention during bulk fermentation, proofing, and baking which results in the oven rise.

The prolamine fraction of gluten, which makes about 40% of the total wheat proteins and is known as gliadin, avenin, hordein, and scaling in wheat, oats, rye, and barley respectively (Lopez Casado et al., 2018), is believed to be responsible for the immune-mediated, enteropathy- stimulated, environmentally- triggered Celiac Disease (CD). A chronic autoimmune disease that affects genetically prone individuals (at all ages) and affects about 1.4% of the world population (Rubio-Tapia et al., 2013). The direct cause of the disease remains unknown, although there is evidence that it results from a genetic defect (Lauret and Rodrigo, 2013) characterized by the absence of an enzyme necessary for gliadin digestion (Leonard et al., 2017). Yet some workers attribute it to an allergic response in the digestive system (Parzanese et al., 2017). Regardless of its pathophysiology, it causes atrophy of the villi and damage to the mucosa of the small intestines responsible for absorption of such nutrients as iron, vitamins, calcium, and folic acid leading to their deficiency.

Worldwide, the prevalence of CD varies greatly, with an estimate of about one in 266 (Ravindra et al., 2018) with the highest prevalence (1.8%) reported in Asia (Singh et al., 2018). Prevalence frequency varies in different geographic areas (Goodyer et al., 2016,). In developed and developing countries, the CD is frequent, particularly in India, the Middle East, and North Africa. Unfortunately, the rate of diagnosis in developing countries is relatively low because of poor awareness and the reduced availability of diagnostic approaches (Catassi et al., 2015). The population of Americans suffering from celiac, gluten intolerance, and wheat allergy is about 1 in every 14 people (Woomer, 2021).

The best approach to deal with CD is to adhere to a gluten-free diet(GFD) (Mahmoud et al.,2013; Bascuñán et al., 2017; Amr et al., 2021). This diet is believed to decrease the risk of complications associated with CD, reverse the disease symptoms, and normalize the histological and laboratory findings (Theethira &Dennis, 2015. Zanchetta et al. (2018) reported that after 3 years of adherence to the GFD diet, CD patients had significantly higher body mass index, body weight, serum levels of 1-25 OH vitamin D, bone mineral density, and significantly lower parathyroid hormone levels and tissue transglutaminase antibodies.

Lately, GFD has been followed by non-celiac patients for other health reasons; consequently, the GF market all over the world has seen significant growth in the last decade with sales reaching 4.63 billion US dollars (USD) in 2017, and are expected to reach 6.47 billion USD by 2023, a projected compound annual growth rate of 7.6% (Woomer, 2021). Several grains like millet, corn, rice, and pseudocereals like buckwheat and quinoa as well as other starchy tubers and roots like potatoes and yams (Casava tapioca) are the main ingredients for GFD. Though most of them have a comparable nutrient profile to common grains, the main challenge to their acceptability by consumers is the sensory quality of their products, functionality during processing, and imbalance of nutrients caused by the use of processing aids like starch, gums, and enzymes.

Wheat bread is the staple food in Arab countries with the annual per capita consumption of Jordanians estimated at 300-500 g. and a contribution to the daily caloric intake of up to 80% (DOS, 2016). Most bread types in these countries are of the flat type characterized by pocket formation, hence the term pocket bread. They undergo shorter fermentation and proofing times than pan bread and are baked at higher temperatures (up to 500°C) for shorter times (one minute or less) which induces steam puffing of the loaves rather than oven rise due to gas production (Amr, 1988). These breads are known by a number of names such as Kmaj, Baladi, Pita, and Arabic bread. They can have moderate or no amounts of crumb and easily rolled and folded, thus making them suitable for playing a functional role in a typical meal, more than calorie carrying as food spooning and holding, plate lining, and preparation of puddings without being soggy, etc… (Amr, 1988).

The objective of this work is to study the suitability of different GF flour sources for the production of thick -flat Arabic bread, and compare their functional, sensory and physical quality characteristics with those of bread produced from wheat flour.

Materials and Methods:

Samples: corn, millet, quinoa, rice, buckwheat grains, and potato and tapioca powders as well as straight grade wheat flour were purchased from the local market in Amman/ Jordan.

Flour preparation:

All grains were pulverized on a hammer mill and sieved on a 177um (US standard no. 80) sieve. The throughs were taken for proximate analysis and bread preparation.

Proximate analysis of the grains and flour:

Moisture, protein, fat, and ash were determined following the AOAC approved methods 971.28,983.14,920.39,942.05 respectively (AOAC, 2005). while fiber was determined according to AOCS no. Ba 6a-05 (AOCS, 2017). The nitrogen-free extract was calculated by subtraction.

Water activity:

water activity of the fresh bread was measured using Novasina Thermoconstanter Model TH 200 (Novasina, Switzerland). A quantity of five grams of each fresh bread sample was placed in sample dish and inserted in the measuring chamber of the instrument at ambient temperature. Water activity reading was taken just when the temperature of the sample became equal to the temperature of the measuring sensor.

Bread preparation:

Lean formula bread was prepared using 1% salt, 2% dry yeast, and water to reach appropriate working consistency (Table 1). The ingredients were mixed in a laboratory dough mixer, and the doughs were bulk proofed for a period of 45 minutes, then punched and left to rise for 25 more minutes, divided into 200 g pieces, rounded and sheeted with a rolling pin, then rested again for 20 minutes and baked at 200°C for 10 minutes, cooled for five minutes at room temperature (immediately) then evaluated by the taste panel(Fig.1).

Quality evaluation of bread:

Sensory quality of the bread was evaluated by a 10 experienced- member taste panel (Amr and Ajo,2005; Mahdy and Abu El-Naga, 2018) consisting of graduate students and employees of the Department of Nutrition and Food Technology/ University of Jordan. The 10 panelists were chosen after excluding 3 others whose responses were significantly ($P \leq 0.05$) different by running Analysis of Variance Test. The panelists were trained on the quality attributes to be evaluated, and asked to evaluate the randomly- ordered (Tomlins et al., 2003) bread samples from the same baking trial on a scale of 1-10 (Husein et al. 1977; Amr and Ajo, 2005; Al-Dalain and Moesy, 2018) for the attributes of pocket formation, and texture as tenderness (Borsuk et al. 2012; Ishida and Steel, 2016) immediately after baking and four hours later and taste. The specific volume was calculated using the sesame seed displacement method (Amr, 1988), and the upper to lower layer ratio of the bread was performed on fresh loaves by weighing the layers and calculating the ratio of the weight in grams of the upper to lower layers.

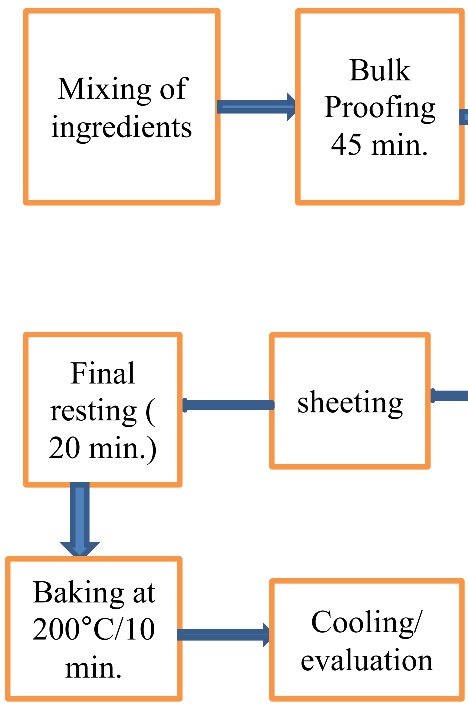

Figure1: Steps of flat Arabic bread production.

Results of the sensory analysis (10 tasters) of each baking trial were averaged and treated as one replicate, and the averages were rounded to nearest whole number. Measurements of the specific volume and upper to lower layer ratios on three wedges from loaves from the same baking trial were treated as one replicate. Three baking trials were performed.

Statistical analysis:

Analysis of Variance (ANOVA) of the data was performed using a Statistical Analysis System (SAS) (2003) program. RCBD design was followed with blocking on replicates. The least Significant Difference (LSD) test was used for mean separation. The study was replicated three times.

Table 1: The water absorption of the flours used in the baking trials .

No.	Flour source	Absorption (water % of the flour weight)
1	Wheat flour	50.0
2	Corn flour	71.6
3	Millet flour	59.4
4	Rice flour	74.0

5	Oat flour	74.0
6	Buckwheat flour	72.0
7	Potato flour	78.0
8	Tapioca	74.6

Results and Discussion:

Proximate composition of the flour sources:

Table 2 shows the composition of the different flours used in the study. All results are in agreement with the values reported by other workers for the same flours (Adebowle et al., 2008; Alvarez-Jubet et al.,2010; Chinma et al.,2013; Moreno Amador et al., 2014; Ali et al.,2015; Niro et al., 2019; Martinez- Villaluenga et al., 2020). It is apparent that both tapioca and rice are the highest in their starch content as the nitrogen-free extract expresses the carbohydrate level which is mostly starch in the case of these two sources. Tapioca is the starch extracted from the roots of cassava plants; it is characterized by its high content of starch and very low content of protein (Adebowale, 2008; Okwu, 2001). Rice also is the second-highest source of starch after tapioca. It is known for its low protein and high starch content (Swamy et al. 2019). On the other hand wheat, corn, millet, and quinoa are the highest in protein with levels ranging between 12.0-13.7% on a wet basis. Quinoa is known for its high protein content (El Sohaimy et al. 2018; García-Parra et al. 2020). it has been used to supplement gluten-free foods with protein (Ramos-Diaz et al. 2020). Gluten-free breads, which lack a gluten matrix, are of poor machinability quality , showing low specific volume, high crumb hardness, and a high staling rate.

Table 2: Proximate composition of the flours used in the study*

Flour	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fiber (%)	NFE (%)**
Wheat	11.45ab ±0.10	0.59e ±0.05	3.45c ±0.03	13.7a ±0.2	2.17d ±0.05	68.65d ±1.0
Rice	12.0a ±0.15	0.41e ±0.006	0.60d ±0.002	7.90c ±0.35	0.50a ±0.001	78.59b ±1.6
Corn	11.9a ±0.17	1.65bc ±0.08	5.50a ±0.08	12.60ab ±0.75	7.10a ±0.32	61.25g ±2.75
Millet	10.10bc ±0.10	2.48b ±0.004	4.30b ±0.06	12.15b ±0.68	6.15ab ±0.25	64.82f ±1.8
Buck wheat	9.00dc ±0.20	3.66a ±0.008	3.23c ±0.07	11.54b ±0.78	7.20a ±0.3	65.37ef ±1.76
Potato	7.00e ±0.16	3.55a ±0.05	0.97d ±0.002	7.85c ±0.40	5.10bc ±0.17	75.53c ±1.98

Quinoa	8.65d ±0.10	1.73cd ±0.07	5.60a ±0.06	12.00b ±0.88	4.25c ±0.18	67.77de ±1.5
Tapioca	12.00a ±0.18	0.16de ±0.001	0.03e ±0.001	0.22d ±0.001	1.01de ±0.005	86.58a ±2.06

*Each mean is the average of 3 replicates ±standard deviation. Means in the same column with the same matching letters are not significantly ($P \leq 0.05$) different according to LSD test.

**NFE= Nitrogen- free extract.

Different non-gluten proteins have been included in gluten-free bread formulations to provide structure and gas-retaining properties to the dough and improve its nutritional quality (Sanchez et al., 2004, Ribotta et al., 2004; Sciarini et al., 2010).

Effect of flour source on the quality of flatbread:

Physical quality parameters:

Table 3 shows the physical quality of the bread as influenced by the flour it is made from. The specific volume parameter of bread reflects the bread crumb quality and quantity, the higher amount and more porous and spongy the crumb, the higher its specific volume. The buckwheat and millet breads followed by the quinoa, wheat, and tapioca had the highest specific volumes (least spongy) . The least specific volume was observed in case corn and potato breads. Potato flour gave sticky and lumpy loaves more similar to pancakes in their texture. This is expected as it had the highest water absorption among all flour types yet a moderate water activity indicating more water was evaporated during baking. Cornbread had lumpy crumb with little eyes in contrast to the bread from millet and buckwheat. The porosity of the crumb indicates better conditioning of the dough and improved ability to hold gas during the fermentation. Oven rise by fermentation gases contributes little to the porosity of the crumb of Arabic bread as oven rise takes place during fermentation, in which gas is lost by later punching. Even rice bread had a better crumb than cornbread.

Pocket formation is another important quality parameter of Arabic bread. It is imperative for the use of bread in sandwich preparation as the loaf pocket holds the food. This follows that bread loaves should be flexible to allow folding for sandwich preparation. All bread types were quite flexible and foldable when fresh, however rice bread became hard and difficult to fold 4 hours after baking, when only wheat and potato breads remained foldable. Pockets are formed of upper and lower layers; the upper layer consists of the crumb-free, gold brown thin crust while the lower layer consists of most of the crumb. Only wheat and potato breads formed pockets although the potato bread crumb was moister than the dry crumb wheat bread.

The upper layer should be lighter in weight than the lower one; hence the upper to lower ratio should be less than unity which was observed in the case of wheat bread. On the other hand, it was much higher in case of potato bread which means that oven rise took place but in a different pattern than in the case of wheat bread.

The presence of the entrapped gas in the gluten network of the wheat dough, along with the steam puffing resulted in producing more gas during oven rise which resulted in the quick puffing and easy separation of the layers. In the case of potato bread, on the other hand, less gas was formed

Table3: Physical characteristics of Arabic thick Kmaj bread produced from eight types of flour *

Flour	Specific Volume (cc/g)[1]	Pocket Formation[1]	Ratio (% w/w)[1]	Water activity (Aw)
Wheat	2.07±0.05bc	6±0.0a	0.83±0.01b	0.91±0.010a
Corn	0.77±0.01d	0c	0c	0.80±0.020c
Rice	2.07±0.04bc	0c	0c	0.9±10.020ab
Millet	3.16±0.02a	0c	0c	0.90±0.008ab
Buckwheat	3.59±0.08a	0c	0c	0.91±0.030a
Quinoa	2.29±0.05b	0c	0c	0.92 ± 0.015a
Potato	1.69±0.01c	5±0.0b	2.03±0.02a	0.90 ±0.024b
Tapioca	1.93±0.01bc	0c	0	0.87±0.032b

- Each mean is the average of 3 replicates± sd. means in the same column with the same matching latters are not significantly different according to LSD test.

during oven rise which resulted in slower puffing and higher amounts of crumb attached to the upper layer. However, this potato bread remained fresh and tender after 4 hours of baking and had a superior flavor to that of wheat bread. Potato flour has high swelling power (Yusuph et al., 2003) and is a unique and acceptable flavor to consumers (Lu et al., 2021). All other bread types Showed poor or no layer separation as they formed loaves with dense masses.

Water activity(Aw) of the fresh bread types ranged between 0.804 in corn bread and 0.918 in quinoa. These ranges are higher than 0.75 reported for extruded flat bread by Marzec et al. (2007). Water activity of bread is influenced by a number of factors including loaf thickness, time and temperature of baking, flour characteristics with respect to its protein and damaged starch content and used additives such as surfactants and others. In our case although potato flour exhibited the highest water absorption (table 1), it never the less gave bread with low Aw reflecting higher water binding capacity of its starch. Water retention capacity and Aw were reported by Sidhu et al (1997) to correlate positively by staling of Arabic bread. Arabic potato bread had the highest tenderness after 4 hours of baking which is due to its high water retention capacity (Zu et al., 2021).

Sensory quality parameters:

Bread tenderness (texture) is an important sensory attribute. In addition to the instrumental methods used for texture evaluation, the texture of bread can be evaluated organoleptically by taters (El-Minyawi and Zabik, 1981). In this study, tenderness was evaluated, by the taste panel, on the freshly baked bread and 4 hours after baking. Buckwheat breads were more tender than wheat bread when evaluated fresh out of the oven; this is due to their moistness as potato and buckwheat flours hold more moisture during kneading than wheat flour (table 1).

Tapioca flour had a detrimental effect on the storage and sensory properties of bread (Piga et al. 2021). Although tapioca flour was not suitable for pan bread production and was recommended for the production of flatbread due to its lowering of the viscoelastic properties of the dough (Marchini et al., 2021), our results indicate that it has a poor freshness score despite its acceptable taste by panelists.

Kumar et al. (2021) reported improved textural and sensory quality of flat, non-pocket forming Indian bread when millet was used with wheat flour in its preparation. While Sharma et al. (2019) reported more shrinkage and water loss, reduced puffing, and starch retrogradation in the same bread types when millet flour was used. Rice flour was used in the preparation of gluten-free flatbread and had better sensory and storage properties than when mixed with millet flour

(Omran & Mahgoub, 2022). The problem with rice bread, as found in this study, is its loss of

freshness shortly after baking and it turned to a rock–hard mass before the other breads.

Table 4: Sensory quality parameters of the bread produced from the different flour sources.

Flour	Tenderness (texture) of fresh bread.	Tenderness (texture) of bread 4hrs after baking.	Taste of bread
Wheat	3±0.5b	2±0.08b	8±0.75a
Corn	1±0.07c	1±0.01c	5±0.50bc
Rice	2±0.06bc	1±0.01c	5±0.45bc
Millet	2±0.02bc	1±0.01c	4±0.45cd
Buckwheat	5±0.03a	1±0.01c	4±0.36cd
Quinoa	1±0.02c	1±0.02c	3±0.07d
Potato	5±0.02a	5±0.07a	6±0.04ab
Tapioca	1±0.01c	1±0.01c	6±0.09ab

*Each mean is the average of 3 replicates (each is the average of 10 responses) ± sd. Means in the same column with the same matching letters are not significantly ($P \leq 0.05$) different according to LSD test

However, four hours later only potato flour retained its complete freshness while wheat and buckwheat breads lost freshness scores. The freshness of potato bread is due to its ability to hold moisture more than the other breads. Staling which was more evident in wheat and buckwheat breads is due to loss of solubility of the amylopectin starch fraction of these breads. Gomathi et al. (2022) used buckwheat in the production of Indian chapattis. They reported improved sensory and nutritional quality of the product. However, buckwheat was reported by Patil et al. (2021) to lower the puffing ability of chapatti bread. On the other hand, Yildiz & Bilgicli (2015) reported the darkening and lowering of sensory effects of buckwheat flour on fermented and unfermented Turkish breads. El Sohaimy et al. (2019) studied the effect of quinoa addition to wheat flour on the quality of Egyptian flatbread and reported acceptable organoleptic and nutritional quality of the product while Cotovano (2021) reported negative effects on firmness and specific volume of Quinoa on pan bread.

Finally, the taste of the wheat bread was more acceptable to the tasters who were accustomed to the taste of such product; yet potato and tapioca breads were accepted by the consumers, though to a lesser degree. Celiac patients can still use potato bread with a well acceptable taste and other functional properties, and use most GF breads in the study for folded sandwich preparation, dipping and spooning. Such patients have to settle for less tasty breads from that of wheat in order to cope with their health situation. Potato flour addition to wheat flour was reported byAl-Kuraieef (2012) to improve the tenderness of flat bread. It is also noteworthy to mention here that in light of the current war in Ukraine, some countries like Egypt are contemplating using potato flour in the flat Balady bread formulas (Amr Mostafa, 2022).

Conclusions:

Flat bread was successfully produced in this study from different gluten free sources with acceptable quality compared to wheat bread. Based on taste and tenderness, potato flat bread, although a poor pocket former, was as acceptable to panelists as wheat bread along with buckwheat bread it had a good taste as expressed by tasters. The problem with pocket formation can be overcome by folding of the loaf to accommodate the sandwich filling instead of a pocket. Poor pocket forming bread can still be used for dipping, spooning of food and soaking without need to form a pocket. All other types failed to form pockets under the conditions of this experiment although most of them had a good specific volume and an acceptable taste comparable to that of wheat bread. Potato bread maintained its freshness 4 hours after baking. By following the recipe elaborated in this study, good tasting GF bread compared to that of wheat, can be prepared by celiac patients from different sources mainly potato and tapioca flours at the home and bakery levels; other sources with acceptable taste including corn and rice can be used in the preparation of such bread at home and bakery levels too. Although taste is the major attribute that determines consumer choice, the decision on which flour to use depends on other factors including the cost of the flour.

Conflict of interest:

Declaration of conflict of interest: The authors declare no conflict of interest in the preparation of this work.

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إنتاج وتقييم جودة الخبز العربي من أنواع طحين خالية الجلوتين

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ملخص

تهدف الدراسه الى إنتاج الخبز العربي من طحين حبوب خالية الجلوتين لمرضى السيلياك ومقارنة جودته بخبز طحين القمح. تم في هذه الدراسة إنتاج الخبز العربي المسطح من طحين القمح والذرة الصفراء والدخن والحنطة السوداء والكينوا والأرز والبطاطا والتابيوكا بطريقة العجن المباشر. تم تقييم جودة الخبز الناتج من حيث خواصه الطبيعية (الحجم النوعي وسهولة الفتح ومعدل الطبقة العليا للسفلى) والخواص الحسية (الطزاجه بعد الخبز مباشرة وبعده بأربع ساعات والطعم). أثبتت نتائج التحليل التقريبي أن طحين القمح هو أعلى أنواع الطحين المستعملة من حيث نسبة البروتين (13.7%) يليه حبوب الذرة الصفراء والدخن والكينوا والحنطة السوداء (12.0%- % 12.6) بينما كان طحين الأرز والبطاطا متوسطي المحتوى من البروتين 7.90 and (7.85%والتابيوكا هي أقلها(0.22%) من حيث نسبة البروتين. أظهرت نتائج التقييم للخواص الطبيعية والحسية أن أرغفة معظم أنواع الخبز تتمتع بأحجام نوعية مقبوله مقارنة بطحين القمح. بينما أظهرت كل انواع الخبز درجة جيدة من الطراوة بعد خبزها إلا أن خبز البطاطا هو الوحيد الذي حافظ على طراوته بعد 4 ساعات من الخبز. كذالك فقد كان طعم خبز البطاطا والتابيوكا هو الأكثر قبولا مقارنة بطعم خبز القمح.

يستنتج من الدراسة أنه بالإمكان إنتاج خبز خال من الجلوتين بخواص حسية ووظيفيه مقبوله أوجيده مقارنة بخبز القمح، خاصة إذا ما إستهلكت طازجه، من معظم أنواع الحبوب موضوع الدراسة وبمستلزمات بسيطة دون إضافات، على المستوى المنزلي والمخبز التجاري.

الكلمات الدالة: الخبز العربي، جودة الخبز، طحين خالي الجلوتين، مرض السيلياك.