EXTENDING THE SHELF-LIFE OF WHEAT BREAD USING PENTOSANES EXTRACTED FROM BARLEY

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ABSTRACT

This research was aimed to delay the staling of wheat bread as one of the most used products globally by adding barley pentosanes, which is neglected and not taken into consideration despite their unique and multiple functional properties and their optimum storage temperature. Water-soluble pentosanes (WSP) and water-insoluble pentosanes (WIP)was extracted from barley (*Hordeum vulgare*) and added to wheat flour at different percentages. Five treatments were prepared: (T1) from flour only, (T2 and T3) adding WSP at levels of (1 and 2%), (T4 and T5) adding WIP at the same levels respectively. All treatments were stored at (20, 4 and -18 °C), for 72 h. The results indicated that the addition of pentosans (WSP and WIP) delayed the staling of bread, especially at the level of addition (2%) for both, when was stored at freezing temperature (-18°C). The results of the control treatment (T1) and the treatments that included the highest addition level (2%) (T3 and T5) and after 72 hours of storage at (-18°C) were as follows: The moisture content of bread crumbs decreased to (39.44, 43.32 and 43.91%) respectively. While the moisture in the bread crust increased to (31.61, 33.98, 34.28%), respectively. The swelling power of the bread crumbs and the sediment volume also decreased to (0.74, 1.18, and 1.03%) and (23, 32 and 33%), respectively, which indicates the potency of pentosans and freezing temperature to delay the staling of wheat bread during the storage period.

Keywords: wheat bread, barley pentosanes, the staling, preservation.
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مجلة العلوم الزراعية العراقية -2023 :54(4):939-949 نشمي و ناصر

إطالة العمر الخزني لخبز القمح باستعمال البنتوزانات المستخلصة من الشعير

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المستخلص

يهدف هذا البحث إلى تأخير تجلد خبز القمح كواحد من أكثر المنتجات استخدامًا على مستوى العالم عن طريق إضافة بنتوسانات الشعير، التي يتم إهمالها وعدم أخذها في الاعتبار على الرغم من خصائصها الوظيفية الفريدة والمتعددة ، ودرجة حرارة التخزين المثلى. لذلك، تم استخلاص البنتوسانات القابلة للذوبان في الماء (WSP) والبنتوسانات غير القابلة للذوبان في الماء (WIP) من الشعير (Hordeum vulgare) وإضافتها إلى دقيق القمح بنسب مختلفة. تم تحضير خمسة معاملات: (T1) من الدقيق فقط ، (T2 و T3) إضافة WSP عند مستويات (1 و 2٪) ، (T4 و T5) بإضافة WIP بنفس المستويات على التوالي. تم تخزين جميع المعاملات في (20 ، 4 و −18 درجة مئوية) لمدة 72 ساعة. أشارت نتائج المعاملات إلى أن إضافة البنتوزان (WSP و WIP) أخرت تجلد الخبز ، خاصة عند أعلى مستوى من الإضافة (2٪) لنوعي البنتوزان، وعند تخزين الخبز في درجة حرارة التجمد (− 18 درجة مئوية). كانت نتائج معاملة السيطرة (T1) والمعاملات التي تضمنت أعلى مستوى إضافة (2٪) (T3 و T5) وبعد 72 ساعة كما يلي: أنخفض المحتوى الرطوبي للب الخبز إلى (39.44 و 43.32 و 43.91٪) على التوالي. بينما زادت الرطوبة في قشرة الخبز إلى (31.61 ، 33.98 ، 34.28٪) على التوالي. كما انخفضت قوة تشرب لب الخبز وحجم راسب عالق اللب المائي إلى (0.74 ، 1.18 ، 1.03٪) و (23 ، 32 و 33٪) على التوالي، مما يشير إلى إمكانية الاعتماد على البنتوزان ودرجة حرارة التجمد لتأخير تجلد خبز القمح لأطول فترة ممكنة.

الكلمات المفتاحية: خبز القمح، بنتوزانات الشعير، التجلد، الحفظ.

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INTRODUCTION

Bread is a staple food around the world and tops the list of the most common foods as many people depend on it. Wheat bread is the most widely used type of bread due to its good sensory properties that are acceptable to the consumer (25). It can be consumed as fresh bread or it can be consumed as commercially packaged bread. The importance of bread has reached the point that it is considered a strategic food that must be secured and supplied at all times of the year, whether in domestic or commercial cases and therefore, it is stored for long periods up to many months (8) . The bread storage indeed succeeded in achieving the desired objective, but on the other hand, it negatively affected the quality of the stored bread because of the phenomenon called "the staling of bread"(15). The staling of bread is a phenomenon that occurs in the bread when it is left for some time, and in general, it begins during the first hours after baking, when are the starch structural change that represents the bread essence and these changes transform it into a complex structure. The starch becomes less able to bind water, and migration of moisture occurs from the bread crumb to the bread crust, which leads to a change in the sensory characteristics of the bread. The staling causes spoilage 26.3% of the bread produced for human consumption all over the world (28). Althoug it was a desire to prevent the staling of bread completely, it is a difficult aim to achieve, but at the same time, several strategies have been found to delay the staling of bread for the longest storage time possible (3). Among these strategies are bread packing using packages manufactured with nanotechnology and using the food additives such as emulsifiers, high-amylose corn starch, potato flour and sugar alcohols, and can also be used chemically or enzymatically modified starch (20, 21). These methods worked to delay the staling of bread, but some of them slowed the fermentation rate of the dough, while others were expensive and significantly affected the sensory characteristics of bread (9). Also, one of the attempts to delay this phenomenon is to increase the fibre content by whole grain flour such as barley, but it causes a decrease in the sensory properties such as appearance, texture, taste and smell, and thus the consumer rejects it(27). Whole grains contain a good amount of fibre, which is mainly composed of pentosanes that possess many important functional properties such as their ability to absorb and water holding at high efficiency. Therefore, it has a great role in enhancing the flour's water absorption, which leads to enhancing the bread retention of moisture after baking and during storage (11). Not only that but also water-soluble pentosanes (WSP) and water-insoluble pentosanes (WIP) can interact with gluten by creating covalent bonds to give it the ability to bind water and affect the distribution of moisture inside the dough and thus reduce the rate of moisture migration from the inner bread crumb to the outer crust. So, it is expected that it has a great role in preserving bread and decreasing the staling of bread rate. The provision of optimum storage conditions such as temperature and humidity is one of the most important tools used to delay the staling of bread because of its low cost and it can be used in combination with another tool to increase the efficiency of restraining the staling of bread(21). Therefore, this study aimed to delay the staling of wheat bread by water-soluble and water-insoluble pentosanes extracted from barley in combination with the optimum storage temperature.

MATERIALS AND METHODS

Preparation of barley flour: Barley grains (Ebaa 99, Harvested in 2019AD) were obtained from the Agricultural Research Center of the Iraqi Ministry of Agriculture. After cleaning, were moistured and conditioned to reach at the moisture of 14% according to (18) . Then, it was milled and the flour was passed through a sieve with holes diameter of 150 microns. The extraction ratio of obtained flour was 78% and 100%.

Extraction of pentosanes

The method mentioned by (12) was used to extract pentosanes (WSP and WIP) from barley flour.

Determination of chemical composition of wheat flour: Moisture, ash, fat and carbohydrates of flour were determined according to (31), Protein and fibers were determined depending on (30, 40) respectively. While, pentosanes in barley was determined by HPLC technique, according to (19).

Determination of chemical composition of pentosanes: Moisture, ash, fat, protein and carbohydrates of pentosanes were determined according to (1, 30 , 31 , 40) respectively.

Preparation of bread (loaf): Bread (loaf) was prepared according to AACC (1) and a proportions amendment of some ingredients, 100 grams of wheat flour were taken and the other ingredients (salt, fat, sugar and yeast) were added at proportions of (1.5, 3, 4 and 2 g/100g), respectively. WSP and WIP were added individually at a ratio (1 and 2%).

Sensory evaluation of bread (loaf): Sensory characteristics were evaluated by 10 evaluators, the evaluation form mentioned from Alzubaidy (46) was used.

Tests of the staling of bread: Four tests were used to measure the staling of bread, the moisture of the crumb and the crust was determined according to (1), while the swelling power of the crumb and the volume of the sediment was determined according to (13).

Storage conditions: The treatments of bread after being cooled and packed in polyethylene bags were stored at room temperature (20 °C), cooling temperature (4 °C) and freezing temperature (-18 °C) for 24, 48 and 72 hours.

Statistical analysis: SAS program was used to analyze the effect of the different factors in the studied traits, mean differences among the averages were compared with the least significant difference at a significance level of p<0.05(19).

RESULTS AND DISCUSSION

Chemical composition of barley flour: Table 1 shows the chemical components of barley flour. The moisture content of barley flour (78% extraction) was insignificantly greater than the moisture content of whole barley flour (100% extraction). This occurs when the conditioning time increases, causing moisture to migrate from the outer surface to the inner layer. As a result, the moisture content of flour produced just from endosperm is larger than that of flour obtained from whole grains(6). Furthermore, moisture loss from the outer layer of the grains is greater than moisture loss from the inner layer of the grains due to mill and grinding process heat, hence partially extracted flour has a higher moisture content (78%) than fully extracted flour (100%) (24). Also, while coming from the same variety, the carbohydrate content of flour (78 %) is higher than (100 %). This is due to the loss and removal of the husks and outer layers and most of the barley grain components, save for the endosperm, which consists primarily of carbohydrates and contributes roughly 85% of the total endosperm and this, is so that high-quality flour can be obtained (42). In the same table, The protein, fat, fibre and ash content of partially extracted flour (78%) was lower than that of full extracted flour (100%) due to the removal of the bran, germ and most barley grain sections, which contain high levels of these constituents. The aleuron and sub-aleuron layers of the bran make up a large percentage of the total proteins in barley grains (44). These proteins as prolamine make up around 52%, whereas glutlen makes up around 23%. Furthermore, the germ contains about 80% of the fatty acids in the barley grain (Zhao et al., 2020). Also, the bran includes 1.5 to 3.5 per cent of the lipids found in the barley grain (44). When it comes to fibre content, the bran is mostly made up of cellulose, lignin, and silica fibres, and removing these layers reduces the fibre content (27).In this context, bran contains several vitamins, potassium, phosphorus, magnesium, iron, and zinc, all of which contain a significant percentage of ash, which means that the ash content in flour is directly proportional to its composition (44). Not only that, but the germ contains a high amount of vitamins that represents a significant proportion of ash, therefore, removing these layers through partial extracting to produce a high flour reduces the ash content (26).

Table 1. Chemical composition of barley flour.

Extraction of barley flour	Chemical composition (%)					
	moisture	protein	Fat	fiberes	ash	carbohydrates
100%	11.2 a	13.8 a	1.45 a	5.73 a	1.29 a	66.93 b
78%	11.4 a	11.9 b	1.05 b	2.56 b	0.95 b	72.14 a
LSD	2.19 NS	1.61 *	0.307 *	1.96 *	0.319*	4.86 *

***Significance level (< 0.05%).**

Barley flour content of pentosanes

The presence of pentosanes in barley flour (78% and 100% extraction) was determined, and the values were recorded in Table (2). The content of total pentosanes, water-soluble pentosanes, and water-insoluble pentosanes in barley flour (78 % extraction) was lower than that of barley flour (100% extraction), the values were (7.49 and 10.25 g/100g), (1.39, 1.55 g/100g), (6.1 and 8.7 g/100g) respectively. This is because bran is mostly made up of fibres, which are mostly made up of pentosanes (27). Wherefore, removing the bran to produce a high-quality flour reduces the total pentosanes content, as well as the content of water-soluble and water-insoluble pentosanes(11).

Table 2. Content of pentosanes in barley flour

Extraction of barley flour	Content of pentosanes (g/100g) WSP	WIP	Total pentosanes
100%	1.55 a	8.7 a	10.25 a
78%	1.39 a	6.1 b	7.49 b
LSD	0.206 NS	1.277 *	1.815 *

***Significance level (< 0.05%).**

Chemical composition of pentosanes

Table 3 shows the chemical composition of pentosanes (WSP and WIP). As shown in the table, the moisture content of (WIP) was lower than that of (WSP) with an insignificant difference at ($p<0.05$), the results were (5.82and 6.16%) respectively. This could be related to the extraction ratio and the level of lyophilization for both of them (12). The results indicate a higher percentage of the protein in the soluble pentosans than the insoluble pentosans (with a significant difference ($p < 0.05$) where their values were (21.8, 13.5%), respectively. Also, the fat and ash content of (WSP) was significantly ($P<0.05$) higher than that of (WIP), the values were (1.45 and 0.77%) and (2.9 and 0.44%) respectively. This agrees with Buksa *et al.* (7) and this is because WSP has a higher protein content, which is linked to a higher proportion of unipolar fats, whereas polar fats are lost during extraction (39). Also, according to Roman *et al.* (37), the high percentage of ash in WSP may be due to its high protein content, which results in increased mineral content such as potassium, phosphorous, magnesium, iron, and zinc, as well as its high-fat content, which results in increased fat-soluble vitamin content. All of these, in addition to its high phenolic acid content. The compounds are the ash's backbone, and an increase in their content leads to an increase in ash content. On the other hand, the carbohydrate content of (WSP) was significantly ($p>0.05$) lower than that of (WIP), the values were (67.69%) for (WSP) while for WIP was (79.45%), and this could be due to an increase in other ingredients, in contrast to that in case of (WIP). The results also revealed that the xylose content of (WSP) was significantly ($P<0.05$) higher than that of (WIP). However, the arabinose content of (WSP) was significantly ($P<0.05$) lower than that of (WIP), the values were (1.45 and 0.77%) and (2.9 and 0.44%) respectively. The water-solubility or insolubility due to a variety of mechanisms is perhaps the most important one of these properties (22, 38).

Table 3.Chemical composition of pentosanes extracted from barley.

Pentosanes	Chemical composition of pentosanes (%) moisture	ash	protein	Fat	carbohydrates	Pentosucrides Total	Xylose	Arabinose
WSP	6.16 a	2.9 a	21.8a	1.45a	67.69b	84.82a	64.57a	20.25b
WIP	5.82 a	0.44b	13.5b	0.77b	79.45a	79.39b	44.45b	34.94a
LSD	1.008 NS	0.67 *	2.70 *	0.86 *	6.31 *	3.28 *	5.49 *	4.31 *

***Significance level (< 0.05%).**

Sensory evaluation of bread (loaf)

The sensory properties of bread were investigated, and the results are shown in Table (4). It has been seen that there were no significant difference ($P <0.05$) among all treatments except for treatment (T3), which had the highest overall score (95.7), while for the other treatments (T1, T2 and T4 and T5). These scores were (89.1, 89.9, 89.4, and 89.3) respectively. These findings are in line with those of Altınel and nal (4), who found that adding pentosanes to bread improved its quality. Also, the other scores for (T3) were reached to higher degrees for most of the examined sensory parameters, such as taste and aroma which comes in the second spot of importance after specific volume, with a degree of (19.1/20). This not only, resulted in a maximum degree of specific volume (30/30), which is related to the functional activites of pentosanes, which enhanced the bread volume through a variety of mechanisms, including the capacity to partial and total fermentation for a dough, as well as the ability to enhance the gluten network, which acts as a fermentation gas preservative (32).

Table 4. Sensory evaluation of bread (loaf).

Characteristic	Degree	T1	T2	T3	T4	T5	LSD
Specific volume	30	27.4 ac	26.7 bc	30 a	27.1 bc	28.8 ab	2.89 *
Color of crust	10	8.5 a	9a	9.5 a	8.7 a	8.5 a	1.18 NS
Symmetry of form	5	4.4 a	4.4 a	3.8 a	4.1 a	4.4 a	0.755 NS
Evenness of bake	5	4.3 a	4.6 a	4.6 a	4.5 a	4.3 a	0.603 NS
Grain of crumb	10	8.7 a	8.8 a	9.5 a	8.8 a	8.5 a	1.06 NS
Color of crumb	10	9.3 a	9.3 a	9.5 a	9.3 a	9.4 a	1.44 NS
Aroma and taste	20	17.7ab	17.8ab	19.1a	18.4ab	17.1 b	1.84 *
Texture of crumb	10	8.8ab	9.3ab	9.7a	8.5ab	8.3 a	1.25 *
Total score	100	89.1 b	89.9 b	95.7 a	89.4 b	89.3 b	5.019 *

***Significance level (< 0.05%). T1: Barley flour only; T2 and T3: adding WSP at levels of (1 and 2%) to flour; T4 and T5: adding WIP at levels of (1 and 2%) to flour**

The staling tests of bread

Moisture of bread crumb: The moisture content of bread crumbs stored at (20, 4, and -18 °C) was determined at different periods of storage, the results were represented graphically in figure (1). From this figure, a gradual decrease in moisture content of bread crumb can be observed during storage at 20 °C, the moisture of crumb for the control treatment (T1) was decreased and reached its lowest level at 72 h, the values were (41.21, 38.27, 35.11 and 34.37%), these results are in agreement with (33 ,43) who mentioned that this is due to the staling process of bread which is also due to the starch retrogradation where the starch normally is at alpha state but during storage, its state changes from alpha to beta state, at this state the starch cannot retain moisture, and Hojjati *et al.* (17) stated that the migration of moisture from the bread crumb to the crust is not only due to the change of starch state but also because it falls under the concentration law, which provides for that the moisture moves from the high concentration area to the low concentration area. Accordingly, the moisture of bread moves from the bread crumb as a high concentration area to the bread crust as a low concentration area. Concerning the treatments (T2, T3, T4 and T5), the charts indicate a gradual decrease in the moisture content of bread crust at a decrease rate lower than the decrease rate for (T1) and this is due to that the pentosanes has a great ability to hold water, so, it has a great role in increasing bread retention of moisture and consequently decrease the rate of staling of bread. Also, pentosanes can interact with gluten to give it the ability to water holding by covalent bonds and thus affect the distribution of moisture inside the dough and reducing the moisture migration rate from the crumb to the bread crust (11). From the same figure, it has been noticed a gradual decrease in moisture content of the bread crumb stored at (4 °C), and at a higher rate than that of bread crumbs stored at the room temperature (20 °C). The moisture content was (33.49, 36.73, 38.43, 37.53 and 38.87%) for (T1, T2, T3, T4 and T5) at 72 h respectively, this is due to that the cooling temperature works on the crystallization of the starch particles and stimulate the moisture lose as a process called the starch regression process, which means loss of the moisture of bread crumb and increasing the moisture migration rate from the breadcrumb to the outside. This leads to the staling of bread three times faster than the bread stored at room temperature (11). In general, can be noticed a gradual decrease for moisture content of the bread crumb during the storage at the freezing temperature (-18 °C), and at a relatively low rate compared with storage at room and cooling temperature, the values were (39.44, 40.35, 43.32, 40.74 and 43.91). %) for (T1, T2, T3, T4 and T5) at 72 h respectively. These results agree with (2), and this is due to that the freezing temperature prevents starch crystallization, which is the major cause of the staling of bread (14). Therefore, bread can be stored at room temperature for a few days, while it can be stored for a period of up to six months at freezing temperature (28).

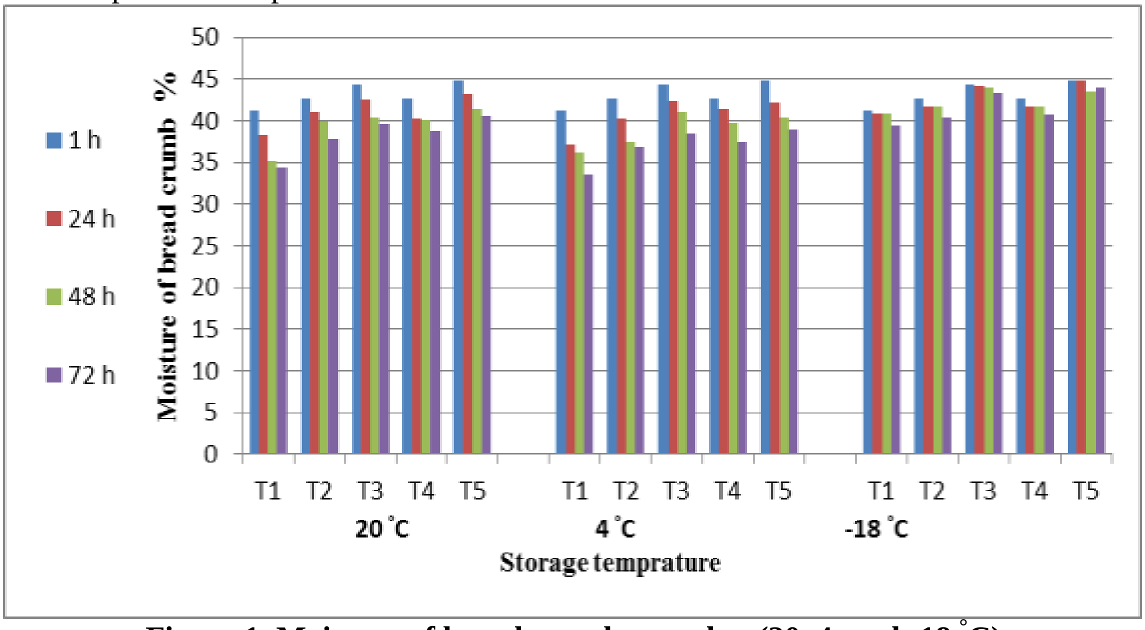

Figure 1. Moisture of bread crumb stored at (20, 4, and -18 °C)
T1: Barley flour only; T2 and T3: adding WSP at levels of (1 and 2%) to flour; T4 and T5: adding WIP at levels of (1 and 2%) to flour

Moisture content of bread crust

The moisture content of bread crusts stored at (20, 4, and -18 °C) was determined at different periods of storage, the results are represented in figure (2). It has been noticed a gradual increase in moisture content of the bread crust during storage at 20 °C, the crust moisture of control treatment (T1) was increased and reached its highest level at 72 h, (28.66%) then (30.25%) then (32.55) and arrived at (34.42%) finally. These results agreed with that obtained by (3 ,33) and this is due to the crystallization of starch particles, or a process called starch retrogradation, where the moisture migrates starting from the bread crumb, passing by the bread crust until arriving outside at this point, the bread loses moisture completely. Therefore, every decrease of the crumb moisture is always accompanied by an increase of the crust moisture, its appearance change for the worse and the consumer rejects it (3). Concerning the treatments (T2, T3, T4, T5). A gradual increase in the moisture content of the crust, at a lower rate was observed, as the crumb was retaining more moisture, that is because of the addition of pentosanes and its role in increasing the moisture retention of the bread crumb and decreasing moisture migration rate to the outer crust (11). It has been noticed that the moisture content of the bread crust increased gradually during storage at (4 °C) and at a rate higher than the bread stored at (20 °C) where the moisture values were (35.89, 36.71, 38.25, 36.87 and 39.17%) for (T1, T2, T3, T4 and T5) at 72 h respectively, these results are in agreement with (14), and this is due to that the cooling temperature workes on the crystallization of the starch particles, which means lose moisture of bread crumb and migration to the bread crust, which causes the staling of bread faster than the bread stored at room temperature (5). Also, this figure shows an increase in the moisture of the bread crust during storage at (-18 °C), but at a relatively low rate compared to storage at (20 and 4 °C), the values were (31.61, 33.88, 33.98, 33.88 and 34.28%) for (T1, T2, T3, T4 and T5) at 72 h respectively, these results are in agreement with (14) who reported that this is due to that the freezing temperature prevents the starch crystallization, which is the main cause of the staling of bread. So, the optimal storage condition for bread for long periods is the freezing temperature, taking into account other storage conditions (28).

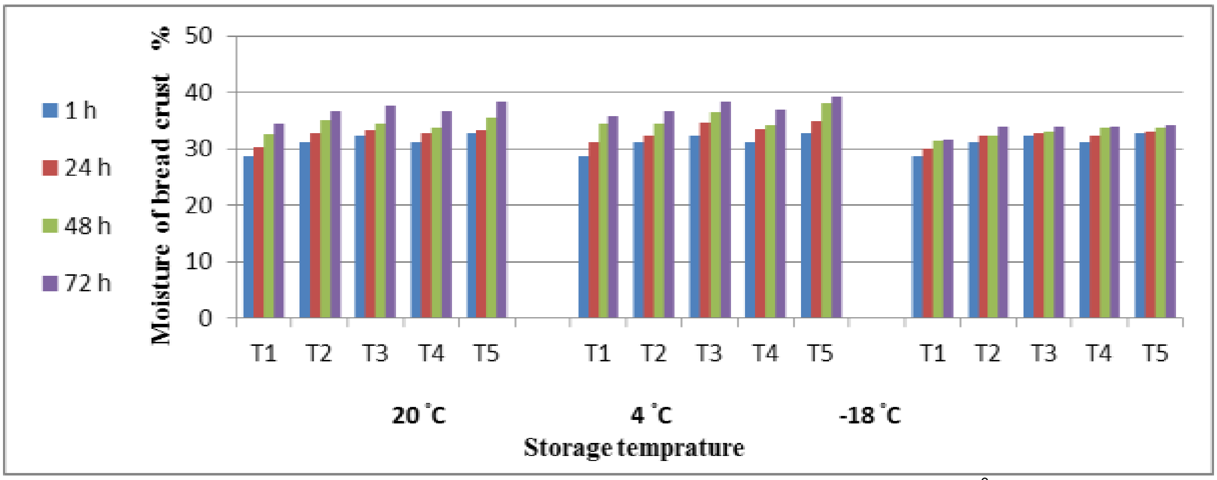

Figure 2. Moisture of bread crust stored at (20, 4, and -18 °C).

T1: Barley flour only; T2 and T3: adding WSP at levels of (1 and 2%) to flour; T4 and T5: adding WIP at levels of (1 and 2%) to flour

Swelling power of the bread crumb

The swelling power of the bread crumb stored at (20, 4, and -18 °C) was determined during different periods of storage, the results were represented graphically in figure (3). A gradual decrease in swelling power of the bread crumb was seen through the period of storage at (20 and 4 °C). The swelling power value of the control treatment (T1) was (0.82%) at 1 h and then decreased after storage for 72 h to (0.59% and 0.54%) at (20 and 4 °C) respectively. The difference between pentosans added treatments (T2, T3, T4 and T5) and the control were not significant ($p<0.05$), when stored at room temperature (20 °C) or Cooling temperature (4 °C) and these results are in agreement with **(16)** who found that the lowest value of swelling power was corresponding to the longest storage period. Generally, the decrease of swelling power of the bread crumb is due to the starch structural change that represents the bread essence and these changes transform it into a complex structure, on this structure, the starch becomes is less ability capable to bind water (5). The swelling power of the bread crumb decreased at a slower rate than that for the bread crumb stored at (20 and 4 °C), the swelling power value was (0.82%) for (T1) after 1 h then decreased to the lowest level (0.74%) after 72 h. While, the swelling power values for (T2, T3, T4, T5) showed a gradual decrease at a lower rate and this is because of the pentosanes and the freezing temperature work on resisting the structural change and crystallization of starch . Thus the starch is maintained its swelling power of water **(10).** Therefore, the best storage temperature for delaying the staling of bread based on the parameter of the swelling power of the bread crumb, is freezing at (-18 °C).

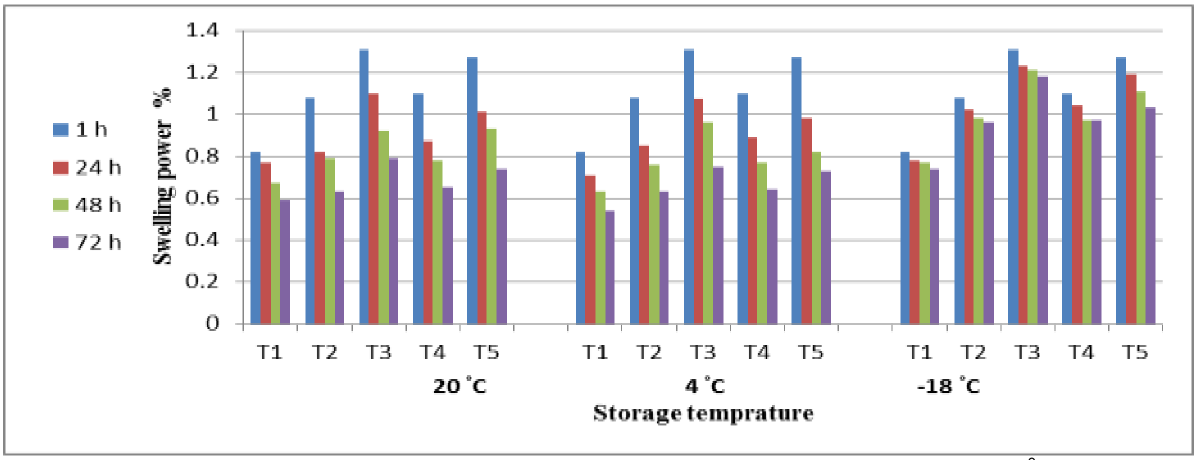

Figure 3. Swelling power of bread crumb stored at (20, 4, and -18 °C)

T1: Barley flour only; T2 and T3: adding WSP at levels of (1 and 2%) to flour; T4 and T5: adding WIP at levels of (1 and 2%) to flour

Sediment volume in the crumb solution

The sediment volume of the bread crumb stored at (20, 4, and -18 °C) was determined at different periods of storage, the results were represented graphically in figure (4). A gradual decrease in Sediment volume of the bread crumb was observed with increasing the period of storage at (20 and 4 °C). The Sediment volume value of the control treatment (T1) was (27 ml) at 1 h and then decreased to its lowest level after 72 h (21 and 22 m) at (20 and 4 °C) respectively. Significantly differences between (T1, T2, T3, T4 and T5) when stored at room temperature (20 °C) or cooling temperature (4 °C) and these results are in agreement with (29) who found that the lowest value of Sediment volume was conformable to the longest storage period. This is due to the starch retrogradation phenomenon, which is the main reason for the occurrence of the phenomenon of staling, after which the starch becomes less soluble in water, and with it the volume of the sediment in the aqueous suspension of the crumb decreases(5). Concerning the treatments (T2, T3, T4, T5), a gradual decrease in the sediment volume was noticed at a lower rate. This is due to the addition of pentosanes which works on resisting the structural change and crystallization of starch, thus increases the volume decrease of sediment in the crumb solution (35). The rate of decrease sediment volume during storage at (4 °C) is less than the rate of decrease in sediment volume during storage at (20 °C). The rate in case of storage at (-18 °C) was the lowest and these results are in agreement with (28), therefore, it can be concluded that the best storage temperature for maintaining the highest volume of sediment as an indicator of bread resistance to the staling phenomenon is -18 °C

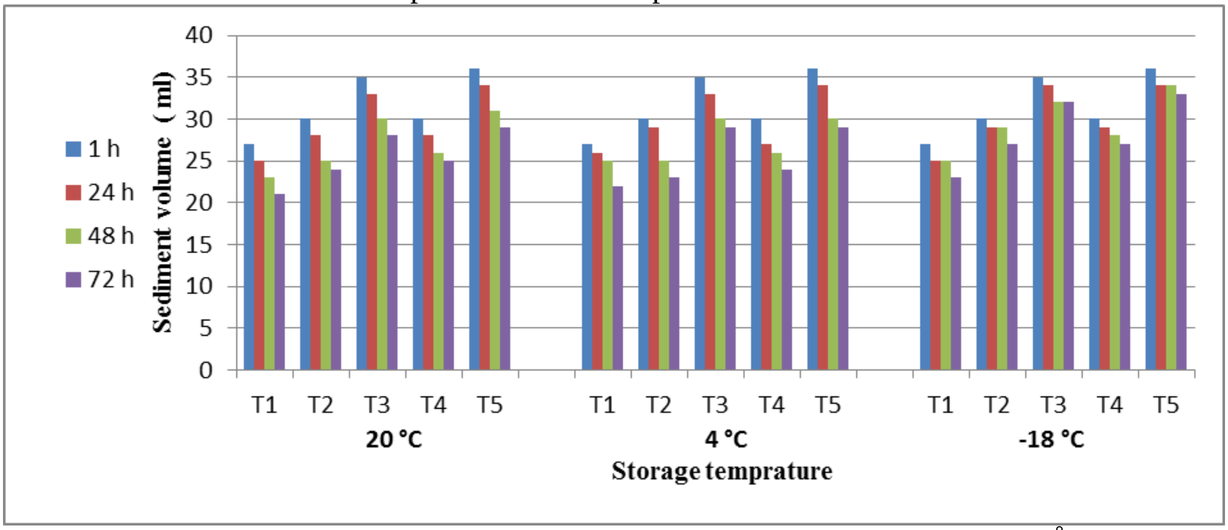

Figure 4. Sediment volume of bread crumb stored at (20, 4, and -18 °C)
T1: Barley flour only; T2 and T3: adding WSP at levels of (1 and 2%) to flour; T4 and T5: adding WIP at levels of (1 and 2%) to flour

Conclusion

This work was felicitous in achieving its objective of delaying the staling of wheat bread by adding water-soluble and water-insoluble pentosanes extracted from barley grains in combination with the optimum storage temperature. Whereas the addition of water-soluble and water-insoluble pentosanes to wheat flour worked to enhancing the bread resistance to the staling generally, (at the highest level of addition (2%) especially and all storage temperatures), Not only that but also storage of bread at freezing temperature (-18 °C) worked on restraining the staling rate exceptionally. Therefore, using pentosans in conjunction with freezing temperature to delay the staling of wheat bread is a low cost, effective and promising method and probably hides many functions and is a good field for many researchers interested in food preservatives.

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