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# Evaluating the Aqueous Extraction Efficiency of β-Glucan Extracted from Local Barley Bran and Endosperm and Studying Some of its Properties

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**ABSTRACT:** This study aimed to evaluate and compare the extraction efficiency of β-Glucan from the bran and endosperm of the local barley variety (Amal) using the aqueous extraction method, driven by the growing nutritional and functional importance of β-Glucan in the food industry. The bran and endosperm were mechanically separated, and each fraction was subjected to aqueous extraction under controlled conditions of temperature, solid-to-liquid ratio, and extraction time. The extraction yield and purity of the extracted β-Glucan were determined using standard analytical methods. The results showed significant differences in extraction efficiency between β-glucan extracted from the bran and that extracted from the endosperm; the endosperm showed a slightly higher extraction yield than the bran. Conversely, the bran extract exhibited distinct functional properties, indicating that the physicochemical properties of this compound vary depending on its location within the grain. The endosperm extract had a molecular weight and viscosity that differed from those of the bran extract. These variations play a major role in determining the efficiency of the extract when incorporated into food systems as a thickening agent or a fat replacer. The study recommends utilizing both fractions as local sources of β-Glucan for functional food formulation, favoring the endosperm when focusing on maximizing extraction yield to improve product texture due to its superior physicochemical properties, and the bran when targeting sustainability and minimizing food waste.

## INTRODUCTION:

Barley (Hordeum vulgare L.) ranks fourth among cereal crops in terms of global production. However, its utilization in the food industry remains limited, being primarily restricted to malt production and animal feed. The variety used in this study is the local cultivar 'Amal', selected due to the urgent need to investigate local genotypes. 'Amal' is recognized for its high productivity and tolerance to prevailing climatic conditions; however, studies evaluating its β-Glucan extraction efficiency remain limited compared to global varieties. Due to the high fiber content in barley, it has become necessary to extract and study a specific type of water-soluble fiber, namely beta-glucan (β-Glucan), which ranges from 2.2% to 19.8% in barley [1]. β-Glucan is a non-starch homogeneous polysaccharide composed of glucose units as its building blocks, linked by β-(1,3) and β-(1,4) glycosidic bonds. Recent studies have indicated that this substance possesses unique properties, including lowering cholesterol levels, regulating blood sugar, acting as an antioxidant, and enhancing immunity [2]. Moreover, β-Glucan has emerged as a highly critical functional ingredient in food science and pharmaceutical sciences [3]. These soluble fibers are located within the cell walls of the aleurone layer and the endosperm in barley [4]. Regarding β-Glucan extraction, [5] indicated

that numerous and diverse extraction methods exist. However, the aqueous extraction method is the most sustainable and environmentally friendly approach, as it avoids harsh chemical solvents, thereby preserving the biosafety and integrity of the extracted compounds. Furthermore, this method is cost-effective and economical [6]. β-Glucan is utilized in food products as an emulsifier, a thickening agent, and a fat substitute, as well as a bioactive ingredient in the food industry, owing to its water-solubility properties [7]. It is characterized by its ability to modify functional properties when incorporated into food matrices, contributing to alterations in the rheological and sensory attributes of the food product. Furthermore, the functional properties of β-Glucan vary depending on its source as well as the extraction method. The extraction method directly influences the molecular weight and, therefore, the viscosity [8]. Due to the global trend towards utilizing natural components, there is a need for an accurate comparison between the products of aqueous extraction from different parts of the grain. Therefore, this study aimed to evaluate the aqueous extraction efficiency of beta-glucan from the bran and endosperm of the local barley variety, and to assess their qualitative differences to benefit the food manufacturing sector and enhance consumer protection by providing high-quality, cost-effective natural alternatives.

**MATERIALS AND METHODS:**

Barley grains (*Hordeum vulgare L.*), variety 'Amal', were obtained from the Agricultural Research Center, Scientific Research Commission, Seed Technology Department. The grains were cleaned to remove impurities, foreign matter, and dust. Subsequently, the hulls (glumes) were completely removed using a specialized grain Al-Habbasha machine.

1. Determination of Moisture:

The moisture content of the grains was determined using a Measure 1200D moisture analyzer (Germany), available at the Quality Control Department of the Grain Trading General Company. Subsequently, the grains were tempered to a target moisture content of 14% according to the method described by [9]. The volume of water added (mL) was calculated using the following equation:

$$\text{Volume of added water (mL)} = \text{Weight of barley} \times \frac{\text{Target moisture} - \text{Initial moisture}}{100 - \text{Target moisture}}$$

The calculated amount of water was then gradually added using a sprayer to distribute the moisture evenly. The grains were thoroughly mixed for 2-3 minutes and placed in a sealed container at a temperature of 20-25°C for 24 hours to improve moisture balance. Laboratory milling was then performed using a Brabender laboratory mill in the Food Science Department laboratory, Faculty of Agricultural Engineering Sciences, and the extraction rate was calculated.

$$\text{Endosperm Extraction Yield (\%)} = \frac{\text{Weight of barley flour (endosperm )}}{\text{Weight of whole barley grain}} \times 100$$

The endosperm was separated from the remaining grain components using a sieve with a mesh size of 0.25 mm, resulting in an extraction rate of 65%. The flour was stored in polyethylene bags in a refrigerator at 4°C until the extraction process. Meanwhile, the collected bran was finely ground using a domestic grinder and was also kept under the same conditions until the beta-glucan extraction process was carried out, in order to make economic use of the milling byproducts.

2. Extraction of β-Glucan from Barley Bran and Endosperm

The extraction was carried out according to [10], with some modifications to the method. The centrifugal force was changed, and the samples were dried by freeze-drying instead of using an air oven. The extraction ratio was 1:10 (w/v) water. One hundred grams each of the milled and separated endosperm and bran were weighed, and 1000 mL of distilled water was added to each. The pH was adjusted to 7 using a 20% sodium carbonate solution. The mixture was then subjected to heat treatment at 55°C for 30 minutes with continuous stirring. The mixture was then centrifuged (10,000 x g) for 20 minutes at 4°C. Subsequently, the pH was adjusted to 4.5 using 2 M HCl to precipitate the proteins. The mixture was then centrifuged at 10,000 × g for 25 min at 4°C, and the precipitate was discarded. The concentrated ethanol (99%) was added at a 1:1 (v/v) ratio, and the mixture was left for 24 h at 4°C. Finally, the mixture was centrifuged at 3,000 × g for 15 min at 4°C. The supernatant was discarded, and the precipitate was collected and homogenized with 99% ethanol, followed by filtration. The precipitate was then transferred from the filter paper into a porcelain crucible and allowed to dry. Subsequently, the sample

was freeze-dried in a lyophilizer at -50°C for four hours. After drying, the product was ground, weighed, and the extraction yield percentage of β-Glucan was calculated. The resulting powder was stored in airtight containers at a refrigeration temperature of 4°C until the subsequent analyses were performed:

- Relative Density and Viscosity

The relative density and viscosity of β-Glucan were measured to determine the effect of the extraction method. The procedure was carried out according to the steps described by [11], where 0.2 g of beta-glucan extract was used and placed in a 50 ml beaker. A small amount of water was added, and the mixture was heated to boiling for 5 minutes using a mixing heater. After that, the temperature was reduced to 77°C and mixed for one hour, then it was reduced to room temperature, and mixing continued for another hour. After that, the pH was adjusted to 6.5 using 4% sodium hydroxide (this procedure is done to prevent clumping), and the solution was homogenized using a manual homogenizer until the heterogeneous particles disappeared, and the volume was completed to 100 ml with a concentration of 2 mg/ml. The density of the extract prepared using the aforementioned method was measured using a density flask at 20°C.

The relative viscosity was measured using an Ostwald pipette after it had been thoroughly washed with water and alcohol and then completely dried. The experiment was conducted at a constant temperature of 20°C. The time required for the liquid to pass a certain distance through the Ostwald pipette was calculated. The process was repeated several times until three identical readings were obtained for the liquid and the water. The two readings were then compared according to the following law, as cited by [12], to obtain the viscosity of the solution, measured in centipoise cP.

$$\frac{\text{Viscosity of distilled water}}{\text{Viscosity of the unknown sample solution}} = \frac{\text{Flow time of water in (s)} \times \text{Density of water}}{\text{Flow time of the sample solution} \times \text{Density of the unknown sample solution}}$$

$$\frac{\eta^1}{\eta^2}\frac{t^1 d^1}{t^2 d^2} =$$

Determination of Water Holding Capacity (WHC):

The water holding capacity of beta -glucan was determined according to the method described by [13]. Briefly, 0.5 g of beta -glucan was weighed and placed into a centrifuge tube, followed by the addition of 10 mL of distilled water. The mixture was blended using a vortex mixer for 1 min and then allowed to stand at room temperature for 30 min, with intermittent vortexing for 5 s every 10 min. Subsequently, the mixture was centrifuged at 6,000 × g for 25 min. The unbound water was discarded, and the tubes were weighed. The water holding capacity percentage was calculated using the following equation:

$$\text{Water Holding Capacity (WHC) (\%)} = \frac{\text{Weight of wet } \beta - \text{glucan} - \text{Weight of dry } \beta - \text{glucan}}{\text{Weight of sample}} \times 100$$

- Determination of Oil Holding Capacity (OHC):

The oil-holding capacity was determined using the same procedure described above, except that sunflower oil was used instead of distilled water. The oil holding capacity percentage was calculated using the following equation:

$$\text{Oil Holding Capacity (OHC) (\%)} = \frac{\text{Weight of wet } \beta - \text{glucan} - \text{Weight of dry } \beta - \text{glucan}}{\text{Weight of sample}} \times 100$$

Based on the theoretical molecular weight according to [13] and relying on the viscosity of the beta-glucan extract, and according to the following equation:

$$ŋsp = (ŋ - ŋs)/ŋs$$

Where:

$$[ŋ] = \frac{ŋsp}{c}$$

$$Mw = \frac{ŋ\frac{1}{a}}{k}$$

Where:

ŋ: is the relative viscosity of the sample

sŋ: is the viscosity of the solvent

ŋsp: is the specific viscosity (ml)

[ŋ]: is the apparent viscosity (ml/g)

C: is the concentration of the solution (g/ml)

K: is a constant of $1.81 \times 10^{-5}$

a: is a constant of 0.93

- Determination of Molecular Weight:

The molecular weight of the extracted beta -glucan was determined using polyacrylamide gel electrophoresis under denaturing conditions (Urea-PAGE) according to the method described by [14] and modified by [15]. The standard barley beta-glucan was electrophoretically migrated alongside the extracted beta -glucan from the endosperm in one run, and from the bran in another. For this purpose, an electrophoresis system manufactured by Pharmacia Fine Chemicals (Sweden) was utilized.

$$\text{Inhibition (\%)} = \frac{\text{Average fungal growth in control} - \text{Average fungal growth in treatment}}{\text{Average fungal growth in the control}} \times 100$$

***Statistical Analysis:***

The SAS Statistical Analysis System User's Guide [16] was used to analyze the data to study the effect of different treatments on the studied traits, according to a completely randomized design (CRD). Significant differences between means were compared using the Least Significant Difference (LSD) test.

**RESULTS AND DISCUSSION**

**Chemical Analysis of Whole Barley Grain and Endosperm Flour**

**Table (1)** Chemical Analysis of Whole Barley Grain and Endosperm Flour of the Amal Barley Variety with 65% Extraction Rate

| Components % | Whole Barley Grain | Endosperm Flour | L.S. D |
|---|---|---|---|
| Moisture | 8.55 % | 13 % | 2.085 |
| Fat | 2 % | 0.9 % | 0.724 |
| Protein | 11.05 % | 9.25 % | 1.368 |

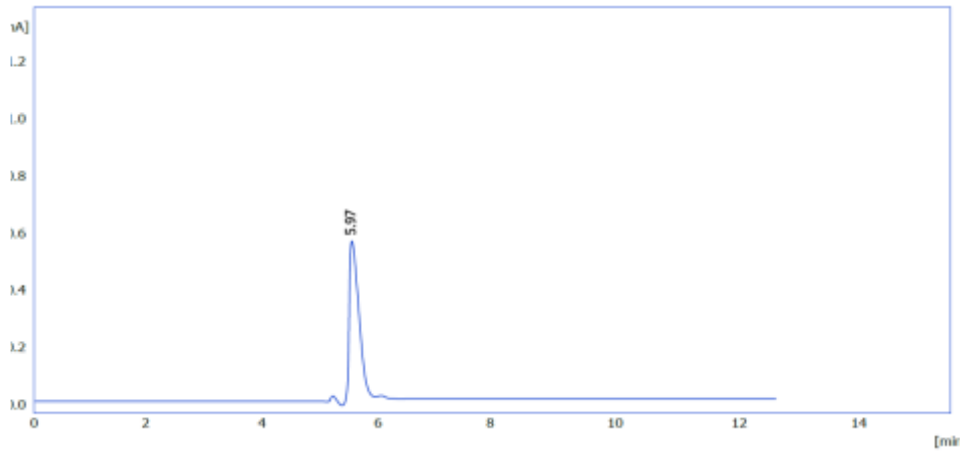
| | | | |
|---|---|---|---|
| Total Carbohydrate | 76.04 % | 75 % | 4.702 |
| Ash | 2.36 % | 1.35 % | 0.677 |
| (P<0.05) | | | |

The results presented in Table (1) illustrate the chemical composition of the whole barley grain and the endosperm flour, at an extraction rate of 65%. The moisture content was 8.55% in the whole grain, whereas it reached 13.5% in the endosperm flour. This increase requires caution, as higher moisture levels stimulate the activation of beta-glucanase enzymes. Comparing the percentage of fat and protein in whole grain and in flour, a decrease in the percentage in flour, as the percentage in whole grain was higher for both. This is attributed to the isolation of the aleurone layer and the germ, which constitute the highest percentage of proteins and fats in the grain. Research by [17] confirmed that reducing the protein content in the raw material before hydro-extraction is a good step, as proteins form a complex with beta-glucan, which reduces the solubility of beta-glucan and increases the difficulty of purification. The results showed that the percentage of carbohydrates in the whole grain reached 76.06%, which is close to that of the endosperm flour, which reached 75%. This is consistent with what was mentioned by [4], who confirmed that non-starchy carbohydrates, such as beta-glucan, are concentrated in the cell walls of the endosperm. For this reason, the endosperm is the main part for extracting soluble fibers with high purity. Therefore, the concentration of beta-glucan increases towards the center of the grain. This explains why the flour retains a high percentage of carbohydrates. When comparing the percentage of carbohydrates with the Ibaa 99 and Ibaa 265 varieties, the percentages were significantly lower than those of the Amal variety, reaching 63.45 and 60.8, respectively, according to what was mentioned by [18]. Regarding the ash content, a decrease was observed in the endosperm to 1.35% compared to 2.36% in the whole grain; this reduction reflects the efficiency of the pearling and sieving processes. This is supported by [19] in a study on the quality of local barley flour, indicating that lower ash content in the endosperm improves the functional properties of the extracted beta-glucan.

Characterization and Quantification of Beta-Glucan in the Lyophilized Extract Using High-Performance Liquid Chromatography (HPLC)

The analytical results indicated that the retention time of the standard beta-glucan matched those of the investigated beta-glucan from both the bran and the endosperm. The retention time for the standard compound was 5.97 min, whereas it was 5.94 min for the endosperm and 5.91 min for the bran. This confirms that the obtained extract is a fraction highly rich in beta-glucan, as illustrated in Figures (1), (2) and (3).

**Figure (1)** HPLC plot of a standard beta-glucan model



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**Figure (2)** The HPLC plot of the beta-glucan sample under study, extracted from the endosperm of barley variety Amal, with an extraction rate of 65%.

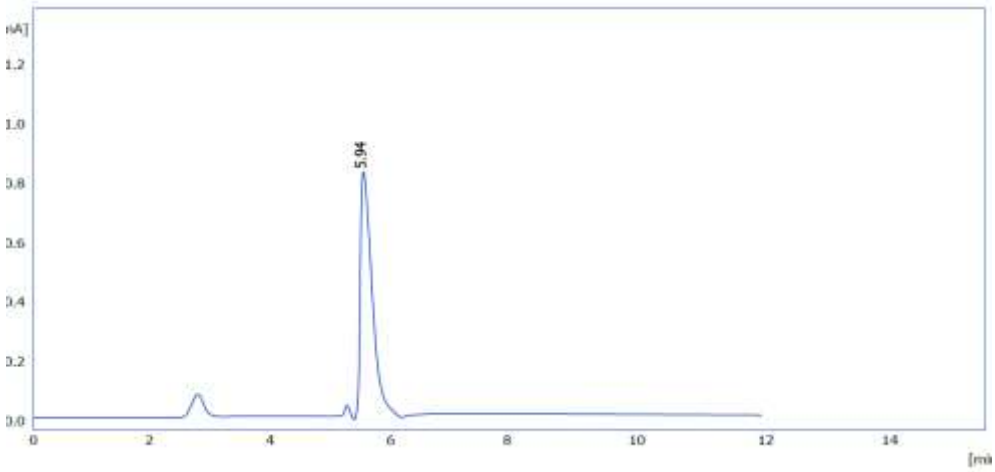
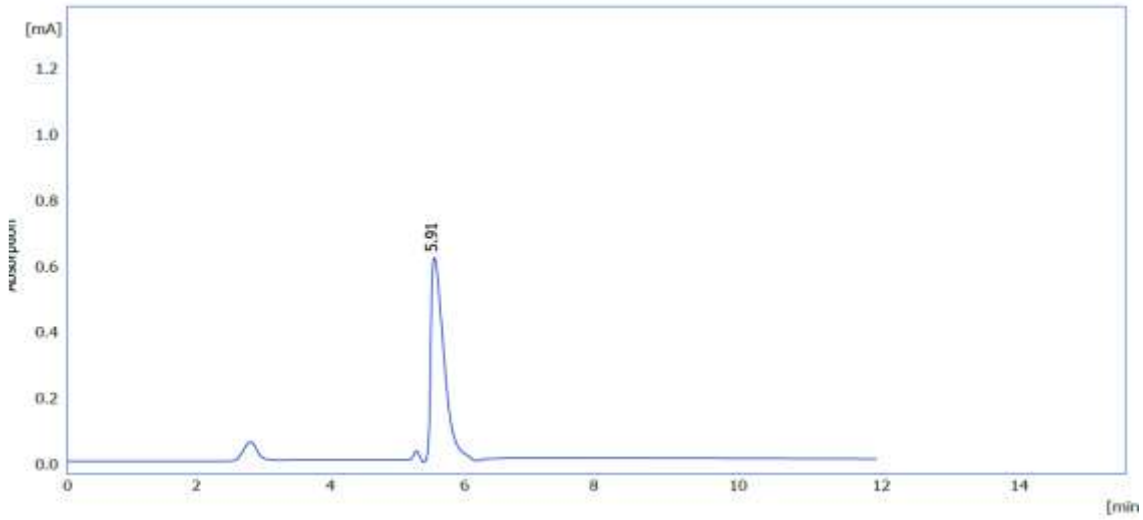



**Figure (3)** HPLC plot of the beta-glucan sample under study extracted from bran




The amount of extract obtained from the endosperm was 2.5%, and from the bran it was 2%. This result is consistent with the findings of [20] in their study of 27 barley varieties grown in Spain, where they found beta-glucans ranging from 2.4% to 7.4% in fully extracted barley flour. HPLC purity testing revealed clear differences. The results showed clear variations; the endosperm extract not only exhibited a superior total extract yield but also achieved a high purity of the active compound, reaching 81%. In contrast, the bran provided an extract yield comparable to that of the endosperm, at approximately 2%; however, its beta-glucan concentration was lower, reaching 38.2%.

**Table (2)** Functional characteristics and properties of beta-glucan

| Model | Relative viscosity (cP) | Water Holding Capacity (WHC) | Oil Holding Capacity (OHC) | Molecular weight (KDa) | |
|---|---|---|---|---|---|
| | | | | Theoretical | Practical |
| Beta-glucan extracted from endosperm. | 1.321 | 703.04 | 661.73 | 312.25 | 174.35 |
| Beta-glucan | 1.181 | 213.75 | 217.24 | 169.54 | 154.61 |

| | | | | | |
|---|---|---|---|---|---|
| extracted from bran. | | | | | |
| L.S.D. | 0.172 $g.m^{-2}$ | 81.66 | 65.03 | 28.58 | 13.91 |
| (P<0.05) | | | | | |

The results presented in the table above showed that the relative viscosity value of the beta-glucan extracted from the endosperm was 1.321 cP, while it was 1.181 cP for the beta-glucan extracted from the bran. These values were comparable to those found by [21], who estimated the relative viscosity of beta-glucan in barley bran (Ibaa-265) at a concentration of 0.1%, pH 7.0, and a temperature of 55 °C to be 1.247 cP. Some studies have indicated that the variation in the relative viscosity of beta-glucan is attributed to differences in the extraction source, isolation and extraction methods, and purity, as it depends primarily on concentration, molecular weight, and the extraction technique [22]. Regarding the WHC, the results showed that the beta-glucan extracted from the endosperm exhibited a high capacity, reaching 703.04%. This value is higher than that reported by [5] for beta-glucan extracted from barley flour (Ibaa-99) at 55 °C and pH 7.0, which was 637%. "Meanwhile, the WHC of the beta-glucan extracted from the bran was significantly lower than its endosperm counterpart, reaching 213.75%. This is attributed to the high purity of the beta-glucan extract obtained from the endosperm. Moreover, [21] indicated that these compounds, due to their high content of hydroxyl groups, possess a strong ability to form a network through hydrogen bonds, thereby binding and trapping water within it. Regarding the OHC, the results in the table demonstrated that the beta-glucan extracted from the endosperm exceeded that extracted from the bran. The capacity was 661.73% for the endosperm extract, whereas it reached 217.24% for the bran extract. [23] demonstrated that beta-glucan extracted from barley bran can bind nine times its weight in water and 1.4 times its weight in fat. This makes it highly effective in food manufacturing, where it is used as an emulsifier in dairy products such as processed cheese and ice cream due to its high fat-water holding capacity. Furthermore, the molecular weight of beta-glucan extracted from the endosperm was higher than that extracted from bran .when comparing the values of the molecular weight of beta-glucan under study with the results of previous studies, it was higher than that found by Al-Laithi and Al Tai (2012 ), which reached $92\times10^3$ Dalltons when they estimated the molecular weight of beta-glucan extracted from barly bran using the HPSEC (High Performance size Exclusion Chromotography )



**Figure (4) b**:Electrophoresis of the beta-glucan model extracted from barley bran



**Figure (4) a**: Electrophoresis of the beta-Glucan model extracted from barley endosperm

## CONCLUSIONS

The study indicated the extraction of β-glucan from the endosperm and bran of the local barley cultivar "Amal". The endosperm showed a slight superiority in its β-glucan compared to the β-glucan in the bran. Despite the proximity of these percentages, the study proved a clear difference in the functional properties between them; it was observed that the viscosity, water-holding capacity, oil-holding capacity, purity level, and molecular weight of the β-glucan extracted from the endosperm were superior to those of its counterpart extracted from the bran. Furthermore, the β-glucan extracted from endosperm was observed to be very white in color, unlike the bran extract, which had a brownish color.

## REFERENCES:

[1] Mejia, S. M. V., de Francisco, A.,andBohrer, B (2020). A comprehensive review on cereal β-glucan: Extraction, characterization, causes of degradation, and food application. Critical reviews in food science and nutrition, 60(21), 3693-3704.

[2] Bezerra, A. S., Nörnberg, J. L., de Carvalho, L. M., Minella, E., & Da Ros, S. (2021). *Effects of genotype and environment on β-glucan and dietary fibre contents in whole grain of barley grown in Brazil* (pp. 549–561). Editora Científica Digital. https://doi.org/10.37885/210203169

[3] Chaudhari, S. B., Gaikwad, S., Polshettiwar, S., & Polshettiwar, P. P. (2025). Beta Glucans: The 21st Century's Multifunctional Key to Drug Delivery. *International Journal of Drug Delivery Technology*. https://doi.org/10.25258/ijddt.15.3.67

[4] Kumar, D., Narwal, S., Virani, S., Verma, R., Gyawali, S., & Singh, G. P. (2020). *Barley grain beta-glucan enrichment: status and opportunities* (pp. 295–308). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-818444-8.00012-2

[5] Al-Mu'adhidi, Ali Ismail Hamed. (2021). The effect of adding barley beta-glucan in the manufacture of low-energy functional yogurt and studying its physicochemical, rheological, and nutritional properties.

[6] Singla, A., Gupta, O. P., Sagwal, V., Kumar, A., Patwa, N., Mohan, N., Ankush, Kumar, D., Vir, O., Singh, J., Kumar, L., Lal, C., & Singh, G. (2024). Beta-Glucan as a Soluble Dietary Fiber Source: Origins, Biosynthesis, Extraction, Purification, Structural Characteristics, Bioavailability, Biofunctional Attributes, Industrial Utilization, and Global Trade. Nutrients, 16(6), 900. https://doi.org/10.3390/nu16060900

[7] Sun, L., Hu, M., Zhao, J., Lv, L., Zhang, Y., Liu, Q.,... and Zhang, Y. (2021).Molecular Characteristics, Synthase, and Food Application of Cereal β-Glucan. *Journal of Food Quality*, 2021

[8] Kaur, R., and Riar, C. S . (2020).Sensory, rheological, and chemical characteristics during storage of set-type full-fat yoghurt fortified with barley β-glucan. *Journal of food Science and technology, 57*(1), 41-51.

[9] Holopainen,U.R.,Pihlava, J.M., Serenius, M.,Hietaniemi, V., Wilhelmson, A., Poutanen, K. and Lehtinen, P .(2014) . Milling, water uptake, and modification properties of different barley (Hordeum vulgare L. ) lots in relation to grain composition and structure.*Journal of agricultural and food chemistry, 62*(35):8875-8882.

[10] Ghotra, B.S., Vasanthan, T, and Temelli, F.(2008). STRUCTURAL characterization of barley β-glucan extracted using a novel fractionation technique. *Food Research International, 41*(10): 957-963.

[11] Burkus, Z., and Temelli, F (1999). Gelation of Barley β-Glucan Concentrate.*Journal of Food Science, 64*(2), 198-201.

[12] Hassan, Abd Ali Mahdi (1987).physical Chemistry of Food Products.Dar Al-Kutub for UNniversity of Mosul.

[13] NO, H.K.; Lee, K.S. and Meyers, S.P.(2000). Correlation between physicochemical characteristics and binding capacities of chitosan products.J.FoodSci. Vol.65,NO.7.

[14] Andrews, A .T. (1983) .Breakdown of casein in bovine milks with high somatic cell count arising from mastitis or infusion with bacterial endotoxin. J. Dairy Res. 50 : 57 – 66.

[15] O'Mahony, S. (2003).Urea-polyacrylamide gel electrophoresis.

[16] SAS. 2018. Statistical Analysis System, User's Guide. Statistical. Version 9.6th ed. SAS. Inst. Inc. Cary, N.C. USA

[17] Yan , J . k ., Wang , W . O., and Wu, J. y. (2014). Recent advances in cordyceps sinensis polysaccharides: Mycelial fermentation, isolation, structure, and bioactivities: A review. *Journal of Functional Foods, 6*, 33-47.

[18] Al-Ali, Firas Abdul Abadi. (2018). Improving the sensory and qualitative characteristics of barley bread using durum wheat gluten and wheat granules. Master's thesis - College of Agricultural Engineering Sciences - University of Baghdad.

[19] Aziz,M.A.,Saeed,F.,Afzaal,M.,Hussain,M.,&Sullivan,P.(2020).Extraction characterization and functional properttties of β-glucan from barley for food application .*Food Chemistry*,https://doi.org/10.1016/j.foodchem.2020.126850

[20] Martinez, M., Motilva, M. J., de Las Hazas, M. C. L., Romero, M. P., Vaculova, K., and Ludwig, I. A. (2018). Phytochemical composition and β-glucan content of barley genotypes from two different geographic origins for human health food production.*Food chemistry,* 245, 61-70.

[21] Al-Laithi, Shatha Abdullah Muhammad Reda. (2011). A study of the functional properties of beta-glucan extracted from local barley and the effect of its addition on the properties of loaf bread. Master's thesis - College of Agriculture - University of Baghdad.

[22] Mäkelä, N., Brinck, O., and Sontag-Strohm, T.(2020).Viscosity of β-glucan from oat products at the intestinal phase of the gastrointestinal model. *Food Hydrocolloids, 100*, 105422.

[23] Al-Azzawi, Shaimaa Saadi Lafteeh. (2018). Using beta-glucan and inulin to improve the physicochemical, rheological, and nutritional properties of low-fat mozzarella cheese. PhD dissertation - College of Agriculture - University of Baghdad.