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Utilization of β-glucan in bio-yoghurt formulation

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ABSTRACT

Yoghurt is considered one of solve tools and therapeutic effect and positive health benefits toward Coronary Heart Disease (CHD) hazards what is known as and called bioyogurt. Then, the main attributes of yoghurt that affect consumer satisfaction are nutrition value, taste, consistency or cohesion yoghurt, and a firm texture. The current study evaluates the influence of barley β-glucan extracts (incorporated in concentrations of 0.05%, 1%, 2%, and 3%) on probiotic yoghurt and shedding light onto the β-glucan capability to improve the rheological and the physicochemical and sensory properties. In addition, elevate the positives effect of barley β-glucan yogurt as a functional food and nutricetical. The set-type yogurt samples were prepared by using raw milk (0.5 %). The statistical analysis showed that β-glucan additions had a somewhat significant effect on pH, titratable acidity, total solids content, and probiotics bacteria counts of yogurt samples compared to the plain sample. Evaluations for syneresis and water-holding capability (WHC) in the yogurt samples showed same effects on the concentration of the β-glucan. Yoghurt treated with 3% β-glucan extracts recorded the highest WHC and gel firmness while least syneresis. Yoghurt samples treated with 3% β-glucan were considered acceptable by panelists and gained the highest scores in sensory evaluations. Results for effects of beta-glucan on the tested parameters were unique could be successfully utilized to mimic full-fat products. Addition of β-glucan at different concentrations significantly increased Radical Scavenging Activity (%) of yogurt treatments at the end storage period and these increments were proportional to the addition ratio compared with plain yogurt. On the other hand, *Streptococcus thermophilus* and *Lactobacillus bulgaricus* counts were gradually increased in all treatments up to 7 days form storage and then decreased at the end of storage period, but remained at sufficient levels (>6 log cfu/g) for up to 14 days compared to the control sample. According to this study, the use of β-glucan as functional phytonutrients are highly recommended for non-fat yoghurt products as new dairy functional foods with improved quality for therapeutic purposes with coronary heart diseases, atherosclerosis, hypertension, obesity, and helps gut microbial balance, which is known as bioyohgurt. However, further studies of these points are needed and take a wider look on the use of barley β-glucan in the yoghurt industry.

Keywords: Bioyoghurt, Probiotic, Yogurt barley β-glucan, FTIR, Syneresis, Viscosity, Color.

1. Introduction

Coronary heart disease remains a major cause of death in Egypt, (according to the most recent WHO data published in 2020 (WHO, 2020).

Abdominal obesity is the most prevalent risk factor (66%)followed by hypertension, as result to food pattern, diet style with high fats and cholesterol, especially take meals is rich in animals fats.

The fact that about 80% of the CVD burden is clustered within developing countries is alarming and calls for more investigation of the current status of risk factors' distribution and treatment strategies implemented to mitigate this risk, especially take healthy foods.

Consumption of foods fortified and enriched with β-glucans can contribute to the treatment of certain chronic diseases. Reduced cholesterol, cardiovascular and diabetic risk and moderate glycemic response of foods have been recorded with the consumption of these biologically active compounds. In

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addition, β-glucans are characterized by anti-cancer, antioxidant, anti-inflammatory and antiviral activities. A number of nutritional studies have shown a link between cereal consumption with the recommended β-glucan content and a reduction in the risks of chronic healthy problems.

Barley is rarely used in the food industry, even though it is a main source of β-glucans, which have important health benefits and a technological role in food.

Barley 1,3, 1,4-β-D-glucans (BG) are dietary fibres with positive health benefits endorsed by the European Food Safety Authority (EFSA) and U.S. Food and Drug Administration (FDA,2005). These benefits include a capacity to lower fasting blood cholesterol and attenuate post-prandial glycaemic responses (EFSA, 2010).

β-Glucans derived from barley have been used for the enrichment of various dairy products such as milk, yogurt and kefir which have been studied concerning their physicochemical properties and potential healthy benefits. Research results indicated that β-Glucan affect glucose and lipid metabolism by different mechanisms (Horton, 2002) and previous reports suggested that the physiological effects to ingested β-glucan rich barley flour. The prebiotic effect of LMW-BG is expected to be applied to several foods and beverages (Kim *et al.,* 2004).

The average molecular weights of LMW-β-glucan and HMW-β-glucan were approximately 12 and 500 kDa, respectively and β-glucan content of LMW-BG and HMW-BG was determined to be 33% and 94%, respectively, using the method of McCleary and Codd (1991) according to AOAC (2007). Another report showed that all of the molecular weight forms of β-glucan (2348, 1311, 241, 56, 21 or <10 kDa) significantly reduced plasma cholesterol concentrations when compared with the control diet (Immerstrand *et al*., 2010).

Food and supplement industries are increasingly interested in concentrating this bioactive grain component at a commercial level to incorporate β-glucans as an ingredient in products formulation, such as yoghurt. Yoghurt is one of the most popular of these dairy-fermented products and is popularly consumed in many societies. Yogurt by itself has been recognized by the medical profession as a healthy food for both adults and children, due to health benefits from high levels of proteins, calcium and vitamins (Sahan *et al*., 2008).

Nowadays, the prebiotic concept has in fact emerged and termed as non-viable and non-digestible ingredients that stimulate gut microbial (Aryana *et al*., 2007). According to Tamime and Robinson, (2007), prebiotics are generally oligosaccharides, whose degree of polymerization ranges between 2 and 20 monomers, which are metabolized by health beneficial bacteria and improve immunity to fight against pathogenic organisms.

Probiotic yoghurt is a term used to describe any yoghurt that contains live, active bacterial cultures. Some of the beneficial effects of consuming probiotics yogurt include:

(1) improving intestinal tract health; (2) boosting the immune system; (3) reducing symptoms of lactose intolerance; and (4) reducing the risk of certain cancers (Parvez *et al*., 2006). The main criteria of yogurt effects on quality and physical properties such as texture, stability and consistency (Zhang *et al*., 2012). This physical structure of yogurt is largely determined by its protein network. After inoculation of milk with the starter culture, a gradual reduction in pH occurs that leads to changes in casein micelle aggregations and this result in formation of a cumulative network surrounded by fat and serum globules (Ahmadi, 2010). Ruas-Madiedo *et al*. (2007) reported the effect of EPSs from lactic acid bacteria in human physiology at different levels. Apart their prebiotic potential, exopolysaccharides (EPSs) have been identified as blood cholesterol-lowering, immunostimulatory, antitumoral and antiulcer agents (Tamime and Robinson 2007).

Set-type yogurt is commonly consumed in middle east and most consumers prefer yogurt with a firm and rigid texture (Amiri *et al*., 2010). Variations in viscosity and syneresis are the most common defects in yogurt, especially in low-fat yogurts. Hydrocolloids are sometimes added to milk to prevent occurrence of unfavorable syneresis (Mathias *et al*., 2011).

In general, the properties of yogurt are influenced by factors such as the specific chemical composition of the milk used in production, the processing conditions and the activity or ability of the starter culture (Mohebbi and Ghoddusi, 2008).

Hydrocolloids are compounds that can improve the texture of yogurt. These compounds include long and branched molecules, which are able to establish links with each other or with other molecules present in the environment in the form of an emulsion. Additions of hydrocolloids to yogurt are effective in absorbing water, increasing viscosity and strengthening and improving the texture of yogurt.

Hydrocolloids also safeguard morphological characteristics of yogurt during storage and transportation (Mathias *et al*., 2011).

Adding too much protein and fat will cause excess stiffness of the gel. For example, casein will make yogurt very stiff and granular and/or more evaporation will cause increased acidity, especially during storage. Therefore, it is better to create the desired properties in yogurt by adding stabilizers (Mathias *et al*., 2011). Several studies have discussed the improvement of physical, textural, flavor and rheological properties of low-fat yogurts by incorporating the stabilizers into the milk (Paseephol *et al*., 2008).

Charles and Carmen (2008) used inulin, guar gum and β-glucan as fat substitutes. The results showed that amounts of stabilizer had a significant impact on evaluations for texture and syneresis of low-fat fermented skim milk. Similar results were reported for fermented cow's milk with an inulin supplement (Guggisberg *et al*., 2009).

β-glucan is also known as a functional and bioactive food ingredient (Du *et al*., 2019). Thus, the demand for food products with a high level of *β*-glucan has been increased worldwide.

Soluble β-glucans have been reported to reduce plasma cholesterol and postprandial serum glucose levels in humans and animals (Keenan *et al*., 2007), and they have been subject of health claims as food constituents by the FDA (United States Federal Drug Administration) and the EFSA (European Food Safe Authority). The claimed effect attributed to β-glucans from barley and oat can be summarized by: "Regular consumption of β-glucans contributes to maintenance of normal blood cholesterol concentrations when ingesting 3g of β-glucan per day*"* (FDA, 2005) and (EFSA, 2010). The cholesterol lowering potential of cereal fiber is considered to result from effects manifested in the upper gastrointestinal tract. These, in turn, may be related to the ability of cereal fiber to form a gel-like network and alter gastrointestinal viscosity (Brennan and Cleary 2005). Viscosity is affected by a large number of factors, such as concentration and MW of the β-glucans, as well as different features affecting the β-glucan backbone (Izydorczyk and Dexter 2008).Therefore, there is a remarkable interest to develop an efficient extraction process of β-glucans from cereals (barleys in particular due to their high content) with the highest molecular weight in order to preserve the healthy benefits related to the viscosity compared with other cereals(oat, wheat, etc)

Apart from being nutritionally important, b-glucans show an important technological role, where they can be used for the elaboration of products with high dietary fiber content as non-caloric thickening and stabilizing agents, as an aid in the production as a fat substitute in dairy products and as a gel-forming component, especially, fermented milks (yoghurt).

It is one of the important compound in the cell wall of the barley and it concentrated in the cell wall of plant seed (endosperm) (ALRubaee, 2008) a large amount of β-*(*1-3) (1-4) glucan about 2-14% of the dry weight of the cells and visco-elastic characteristics of β-glucan gels are related to the molecular weight of the isolated fractions. Differences in molecular weight were observed among β-glucans extracted from different cultivars of barley (Laroch and Michaud, 2007). According to Beer *et al.* (1997) barley Glucan is linear non-branched β(1,3)(1.4) and molecular Weight $0.15x10^6$ *P*- $2.5x10^6$.

To this purpose, the present study aims at shedding light onto the beta-glucan capability to improve the firmness or hardness, after short-term cold storage, of skim milk fermented by specific bacteria, effects of barley β glucan on the physicochemical and sensory properties of probiotic yogurt samples. Raise positives effects as therapeutic food or functional food and nutricetical, possibility of application of β-glucans incorporation with foods, especially dairy as therapeutic food. Especially to, the latest WHO published data in 2020 Coronary Heart Disease Deaths in Egypt reached 173,871 or 32.40% of total deaths. The age adjusted Death Rate is 268.11 per 100,000 of population ranks Egypt 15 in the world. Abdominal obesity was the most prevalent risk factor (66%)followed by hypertension, as result to food pattern, diet style with high fats and cholesterol, especially take meals is rich in animals fats.

2. Materials and Methods

Raw materials

Milk

Fat free milk used in this study was obtained from a local dairy processor (EL-Beheira governorate) and processed on the same day. Milk was standardized to a fat level of 0.5 % by prepared by separating raw whole milk using a Westfalia separator.

Stabilizer

Commercial grade barley β-glucan (Food grade standard barley β-Glucan, 86% β-Glucan) produced by Johncan Mushroom Bio-Technology company (Zhejiang, China).

Barley flour characterization

Barley (*Hordeum vulgare*, variety Giza 2000) was provided by FCI (Field Crops Institute, ARC, Giza, Egypt). β-glucan content of this cultivar was 6.5 % and starch content was 52.3 %, both expressed in dry basis. The sample was manually cleaned to remove unwanted materials and damaged grains and then refrigerated at (5°C). The sample was brought at room temperature, the final barley grains were finely ground by a regular laboratory mill and passed through a 60 mesh screen (d = 0.25 mm) to achieve homogeneous particle size that, in turn, reduce the problem of scattering during NIR data acquisition. Barley flours were further used for chemical and spectral analysis. The barley flour used in the study had a composition of 10.6% moisture, 11 % protein, 2.3 % lipids, 1.4 % ash, 11 % insoluble dietary fiber and 6 % soluble dietary fiber. Then β-glucan was extracted from whole barley flour using Wood *et al.*, (2002) procedure with some modifications (Prior to the extraction procedure, barley flour was boiled with ethanol (99.9%, v/v) under reflux for 2 h in order to inactive β-glucanases (to avoiding enzymatic hydrolysis), and left it air dried with constant flow for 1.5h.

Extraction of β-glucans Barley flour.

According to the method described by Wood *et al.* (2002) with a few modifications as the following:

1- 100 g of the barley flour sample was added to 1 L of distilled water at an adjusted pH by calcium carbonate (20% p/v) and warmed in a water bath with agitation for 30 min. The solution was centrifuged at 4940xg/30 min and 4 **ºC** to separate precipitated starch, which were discarded.
2- pH of the supernatant was adjusted to 4.5 with HCl 2 mol L, centrifuged at 4940xg/30 min 4 ºC to separate precipitated proteins, which were discarded according to Yalcın and Celik (2007).
3- An equal volume of ethanol (99.9%) was added to the supernatant to precipitate the β-glucans.
4- After 12 h at 4 ºC, the solution was centrifuged at 3780xg/10 min. The precipitate was re-suspended in ethanol, filtered, rinsed with ethanol and dried in an oven at 25 ºC with forced air circulation for 1.5 h. The dried β-glucan extract was stored in a desiccator for 24 h and then ground it.

β-Glucan Content

β-glucan content was evaluated according to McCleary and Codd (1991) *in the* initial barley flour (raw barley) and in the solid phase after the extraction *(*exhausted barley*)* by using β-glucan enzymatic assay kit (Megazyme International Ireland Ltd., Wicklow, Ireland) β-glucan extraction yield was evaluated according to Equation:

$$\textbf{β-glucan extraction (\%)} = \frac{\%\ \beta\text{-glucan in raw barley} - \%\ \beta\text{-glucan in exhausted barley}}{\%\ \beta\text{-glucan in raw barley}} \times 100$$

The yield of crude b-glucan extract was calculated on 100 g barley flour basis.

Physicochemical characterization of β-glucan

During the extraction process, the extract was conserved at 20 ºC, and the moisture content was determined according to AOAC (2007). pH was measured with a pH-meter at room temperature. Ash was determined by incineration in the oven at 600 ºC and fat content by Soxhlet extraction with petroleum ether, Nitrogen was determined by Kjeldahl method and protein content was calculated by

multiplying the rate of nitrogen by 6.25. Carbohydrate content is calculated by subtracting from 100%, moisture, fat, protein and ash (Liu *et al.,* 2007).

Fourier Transform Infrared Spectroscopy (FTIR)

The β-glucan fraction was chemically characterized by Infrared transmission spectroscopy (FT-IR) in Lab of FTIR, National Center of Researches, Giza, Dokky, Egypt. ATR- FT-IR was measured using Bruker VORTEX 80 (Germany) combined Platinum Diamond ATR, comprises a diamond disk as that of internal reflector in the range of 4000- 400 cm^{-1} with resolution of 4 cm^{-1}, reactive index 2.4, and the measurements were performed in duplicate.

Determination of antioxidant activity

DPPH scavenging activity%

Scavenging activity of the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical (from Sigma-Aldrich (Munich, Germany) was determined according to the procedure based on Brand-Williams *et al*. (1995). Two milliliters of 0.15 mM DPPH were added to 1 ml of extracts in different dilutions. A control was prepared by adding 2 ml of DPPH to 1 ml of methanol. The contents of the tubes were mixed and allowed to stand for 30 min, and absorbance was measured at 517 nm using a spectrophotometer (Pg T80+, England). Triplicate tubes were prepared for each extract. The results were expressed as % radical scavenging activity.

$$\% \text{ Radical Scavenging Activity} = \{(A \text{ control} - A \text{ sample}) / A \text{ control}\} \times 100$$

While, the IC_{50} which denotes the amount (mg) of the plant extract in 1 ml solution required to reduce initial concentration of DPPH radicals by 50% was also calculated. Ascorbic acid (obtained from Loba Chemie, Mumbai, India) was used as a standard.

Functional properties of β-glucan

The used method to determine the water-holding capacity, was the same described by Thammakiti *et al.* (2004). The percentage of water-holding capacity was calculated as the amount of additional water held by 100 g of sample having an original moisture basis about 14%. While the viscosity of 1% (w/v, basis) dispersion of β-glucan in water was measured from the obtained curve of shear stress/shear rate of β-glucan, whereas, effect of temperature on the β-glucan viscosity was also studied (Singh and Kaur 2017).

Preparation of starter cultures

Yogurt starter containing *Lactobacillus delbrueckii ssp. bulgaricus* and *Streptococcus salivarius ssp. Thermophilus* (1:1) having cellular concentration of 10^8 cells/g, used for inoculation, were obtained from the Microbiological Resources Center (MIRCEN), Faculty of Agric. Aim Shams Univ., Egypt. The packages of starter were prepared according to the manufacturer's instructions.

Preparation of yogurt

Skimmed milk was prepared by separating whole raw milk using a cream separator at 40 ºC. Skimmed milk, was divided into five parts, control yoghurt and β-glucan extraction composite were added in level of 0.05%,1%, 2%, and 3% and dissolved in milk with stirring at high speed for 5 minutes at a temperature 25 °C until homogenized .Then pasteurized at 85 °C for 10 min and cooled to 45 °C, inoculated with a starter culture at a ratio of 1% (w/v), dispersed into plastic cups, 100 g, and incubated at 40 °C until pH 4.7.(until reaching an acid value of about 90 - 95 ^{0}D), where, the coagulation kinetics of samples was determined by monitoring the acidity every half hour, and from the fourth hour, it was done each fifteen minutes until the end of coagulation **(**Sandoval *et al*., 2004). Following incubation, all samples were kept at room temperature (25 ºC) for 30 min and moved to a cold room. The yogurt samples were stored at 4 ºC for 14 d and sampled at 1,7 and 14 days of storage for assessment and testing of physiochemical, rheological properties and viable count cell in triplicates.

Chemical analysis of bioyogurt

Total solids content of yogurt samples were determined according to AOAC (2007) method 990.20. The pH values were measured using a digital pH-meter at 25 ºC which was previously calibrated with pH 7.0 and 4.0 standard buffers. The titratable acidity was determined according the AOAC (2000) titration method. Acidity was determined by titration with 0.1 N NaOH using phenolphthalein as an indicator color. Results were expressed as degree Dornic. (Each degree equivalent to 0.01% lactic acid per milk liter, normal values are around 15). All samples were prepared and analysed as triplicates.

Rheological characteristics of bioyogurt and plain yogurt.

Syneresis

Twenty-five grams of yogurt samples were weighed on a filter paper placed on top of a funnel (W1). Syneresis of whey was carried out by gravity and the quantity (grams) of whey collected in a flask of known weight was used as a syneresis value. The drainage time and temperature was 120 min and +4℃, respectively (Sahan *et al*., 2008)

$$\text{Syneresis (\%)} = \{(W_2-W_1)/W_1\} \times 100$$

where W_2 is the weight (g) of drained liquid and W_1 is the initial weight (g) of the sample**.**

Water Holding Capability

According to the method of Parnell-Clunies *et al*. (1986), a 10 g sample was centrifuged at 3,000 g for 30 min at 4ºC. The supernatant was then removed within 10 min and the wet weight of the pellet was recorded. The WHC was expressed as the percentage of pellet weight relative to the original weight of yogurt. The WHC was calculated as follow: $WHC = 1 - (W_2/w_1)x100$

where, W_2 is the weight (g) of supernatant and W_1 is the initial weight (g) of the sample (Sahan *et al*., 2008).

Gel firmness

Gel firmness of yogurts were determined at 4-6 ºC by penetration measurements (Texture Analyzer, Brookfield) equipped with a 4.5 kg load cell. The instrument was adjusted to the following conditions:

Cylindrical probe (38 mm in diameter); penetration speed, 1 mm/s; penetration distance, 30 mm into surface. The peak force was measured in grams (Cruz *et al*., 2010)

Viscosity measurements of experimental yogurt.

Viscosity of 1% (w/v, basis) dispersion of β-glucan in water was measured from the obtained curve of shear stress/shear rate of β-glucan, whereas, effect of temperature on the β-glucan viscosity was also studied (Singh and Kaur 2017). Meanwhile, the viscosity of yoghurt samples were measured by the method of Aryana (2003) using Rotational Viscometer Type Lab. Line Model 5437. Results were expressed as Cps. The power law equation was used to describe the rheological behavior of the yoghurts over different shear rate as: $\sigma = k(y^n)$.

where σ is the shear stress (Pa), k is the consistency coefficient (Pa s), c is the shear rate (1/s), and n is the flow behavior index (dimensionless).

Color

Color (*L**, *a**, *b**) was measured by using a Minolta colorimeter (MINOLTA R300). In this system the L* represent the lightness, *a** the red value and *b** the yellowness: + *a** is the red, -*a** is the green, +*b** is the yellow, and – *b** is the blue directions (Cueva and Aryana 2008).

Microbiological assays

Serial dilution were performed in duplicate, where made in yogurt samples at the end of the storage period (28 days). For that, 1 g of each yogurt was decimally diluted in sterile peptone water 0.1%, and 0.1-mL aliquots dilutions were spread over the surfaces of plates of SMA to enumerate the total LAB from the yogurt starter cultures, and 1 mL was plated in yeast extract-glucose-chloromphenicol agar (YEGCA) to enumerate molds and yeasts (Sanders., E.R. 2012). Plates were

incubated at 37 °C- 48 h for the counting of the total LAB, and at 25 °C-5 days for the counting of molds and yeasts. All media were obtained from Merck (Darmstadt, Germany). Colony forming units (CFU) were enumerated in plates containing 30 -300 colonies, and cell concentration was expressed as log CFU/mL.

Sensory analysis

The sensory evaluation of the yogurt samples was carried out according to Mehanna *et al*. (2000). The scores used were 60 points for flavor, 30 points for body and texture, and 10 points for appearance, with an overall score of 100.The sensory panel involved 10 panelists (well trained, having knowledge of sensory attributes and ability to access and rate the sensory parameters), aged between 27 and 55 years . The samples were taken out from the refrigerator and put into bowls just before the evaluation. The tests were carried out in a controlled, and 25 ml of the yoghurt was served at a temperature of 5 °C using plastic cups codified suitably environment (Hamad and El-Nemr 2015). The panelists were instructed to evaluate the yoghurt samples with respect to the degree of their liking using a nine point Hedonic scale from (1 = Disliked extremely, to 9 = Liked extremely), sequentially on different days indicating that each panel member tested five yoghurt samples in one stretch in two occasion with each yoghurt sample prepared in duplicate. The members were guided to drink water between samples testing to wash the mouth. The samples were rated on the basis of the parameters of physical appearance, mouth feel, taste, color characteristics, kinesthetic (hardness, cohesiveness, and adhesiveness), and overall acceptability.

2.1. Statistical analysis

Data were statistically analyzed using the general linear models procedure of the statistical analysis system SAS (1998). Significances of differences were defined at $p < 0.05$.All experiments were repeated three times and all obtained data are expressed as an average.

3. Results and Discussion

3.1. Physicochemical properties of barley β-glucan

The results in (Table .1 and Fig.1) represent the chemical composition of β-glucan the extracted by 6.7 % /100 g barley flour and purity grade 92.8 % was composed from 3.1 moisture, protein 2.1,ash 2.01and fat 0.5 %, respectively.

On the other hand, The total antioxidant activity of β-glucan obtained in terms of DPPH free radical scavenging activity was 29% and is considered as having an excellent antioxidant activity .For the reason, it is recommended to use β-glucan mixed in dairy, especially fermented milk. In the present study, water binding capacity value of β-glucan extract obtained were 3.17 g/g (Table 1). This value is agreed with the results of Subaric *et al*. (2011).

Table 1: Physicochemical and functional properties of extracted β-glucan

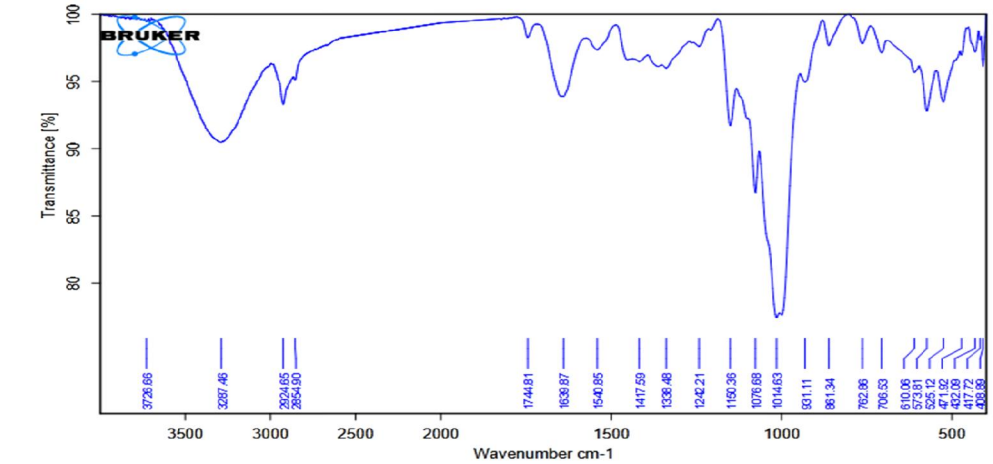
Parameters	Moisture %	Protein %	Ash %	Fat %	β-glucan %	DPPH activity %	WBC g/g
β-glucan extracted/ 100g.	3.10 ± 0.3	2.10 ± 0.0	2.017	0.5	92.80%	29.0 ± 0.5	3.17 ± 0.30

Meanwhile, measurement of WHC is important for estimating the syneresis of fermented milks as a functional ingredient to avoid syneresis problem in various food products. Where, the swelling power of β-glucan depends on the water holding capacity of molecules by molecular hydrogen binding abilities (Lee and Osman 1991). WHC properties of β-glucan are essential for many food uses and have an impact on shelf life of food product since it reduce weeping on the surface which prevent texture loss, syneresis and microbial growth. These functional properties have been considered an important when β-glucan is used as a functional ingredient and stabilizer in the food industries, where often a high binding capacity and stability is essential.

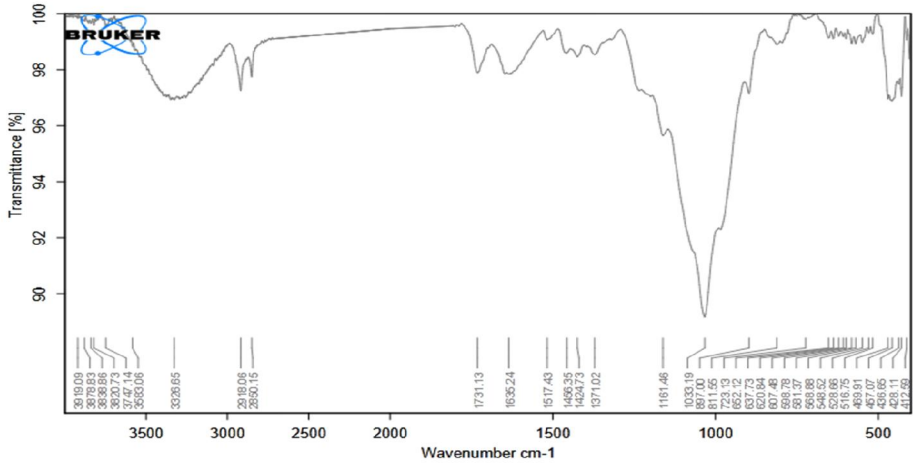
Analysis of Glucan by FT-IR

FT-IR technology is used for the organic molecule diagnosis by detecting the active groups and bounds found in the molecule (Ibrahim *et al*., 2006).

Result in Fig. (2.a) showed that infrared spectrum at the absorbance 1041.5 cm^{-1} means the presence of C-O-C bonds which is a characteristic feature for β-glucan structure stretching with the standard 1051cm^{-1} (Fig.2.a) (Hozova *et al*., 2007).



(a)



(b)

Fig. 2 a,b: FTIR of standard β-glucan, commercial and extracted β-glucans

The absorbance at (1384.8 cm - 1) refers to the presence of C-H aliphatic bending; the standard absorbance was at 1375cm^{-1} (Karreman *et al*., 2006), because barley Glucan is linear non-branched β(1,3)(1.4) and molecular Weight 0.15x106 P- 2.5x106 (Beer *et al*.,1997).

On the other hand, free hydroxyl groups and carboxyl groups were absorbed at regions 2862.2 cm^{-1} and 2923cm^{-1} that found in the carbohydrate (Ibrahim *et al.,* 2006).

Glucan was analyzed using FT-IR spectroscopy to detect the functional group in its chemical structure of glucan, and compared these groups with standard ones.

The infrared spectra of extracted and commercial β-glucans are shown in (Fig. 2 a and b). In the region of 3500–3000 cm^{-1}, the extracted and commercial barley β-glucans spectra showed a wide band with maximum absorption (minimum transmittance) at 3287.46 cm^{-1} and 3326.65 cm^{-1} respectively. This can be attributed to normal vibration modes of asymmetric and symmetric stretching of OH groups because polysaccharides contain a significant number of OH groups, which exhibit an absorption band above 3000 cm^{-1} (Wang *et al*., 2008).

The maximum absorption peaks occurring at 3287.46 cm^{-1} (extracted) and 3326.65 cm1 (commercial) β-glucan, in the region of 3500-3000 cm^{-1} could be attributed to the relative values of the

vibration modes of asymmetric and symmetric stretches of CH groups (V*ie*ira, 1998). Therefore, the peaks at 1076.68 cm^{-1} for the extracted β-glucan sample and at 1161.46 cm^{-1} for the commercial β-glucan one indicate the presence of glycosidic bonds and cyclic structures of monosaccharides (Hozova *et al*., 2007). In addition,result indicated that the FT-IR spectra of the extracted β-glucan from barley had appearance typical to that of the standard β-glucan with high degree of purity and absence of the protein contents that absorbed at 1635, 1542, 1650 cm^{-1} (McCann *et al*., 1992).

The β-glucan content was 6.7 % in Whole barley flour, similar results were described by Fujita and Figueroa (2003) for Brazilian barley cultivars. Barley flour composition indicates that barley is a good source of β-glucans. Infrared spectroscopy allows the measurement of molecular vibrations of covalent bonds. The IR region 3500-500 cm^{-1} provides information on the fundamental vibrations of β-glucan. On the other hand, the region 1014.63-408.89 cm^{-1}, which showed peaks with maximum absorption at 1014.63 cm^{-1} (extracted) and 1033.19 cm^{-1} (commercial) β-glucan, corresponds to COC and CO bonds (Wang *et al*., 2008) of a ring of D-glucose, which are network vibrations in which all of the atoms of the macromolecular chain vibrate in phase and normal modes resulting from coupling of the CC and CO stretches (Vieira, 1998).

Carbohydrates can be recognized by peaks at wave numbers of 1076.68 cm^{-1} (CO bond of the alcohol group), 2924.65 cm^{-1} (CH stretch) and 3400 cm^{-1}(OH stretch) (Wang *et al*., 2008). The parameters evaluated in the partial characterization of extracted β-glucans are favorably compared with the commercial β-glucan in their high degree of purity.

Physicochemical properties of control and experimental yogurt samples:

Chemical composition

Table (2) show chemical composition of control and experimental yogurt samples. Total solid contents of the samples were similar in all yogurts with barley β-glucan. The addition of β-glucan into the milk increased somewhat the total solid contents in the yogurts.

Table 2: Chemical composition of non-fat yoghurt (control) and samples made with β-glucan ratios.

Samples	Total solid (%)	Fat (%)	Protein (%)	Ash (%)
Control Sample	12.79±0.35	0.1±0.01	4.85±0.53	1.12±0.3
β-glucan.05%	13.19±0.36	0.1±0.01	4.95±0.53	1.17±0.04
β-glucan 1%	13.48±0.14	0.1±0.01	4.97±0.33	1.28±0.02
β-glucan 2%	13.45±0.14	0.1±0.01	4.99±0.43	1.39±0.03
β-glucan 3%	13.60±0.14	0.1±0.01	4.99±0.65	1.40±0.04

*($P<0.05$, n=3), Presented values are the means (±SD) of three replicate

Acidity and pH

(Table -3) show that pH and acidity values were similar for all the yogurt samples, pH of the control yogurt sample was4.40, while the pH values of other treatments ranged from 4.42 to 4.44. Titratable acidity ranged from 116 to 121 ^{o}d.

On the other hand, concentration of β-glucan had no significant impact on levels of acidity and pH of the yogurt treatments at $p<0.05$. The same results were obtained by Sahan *et al*. (2008) with yogurt supplemented with β-glucan. In addition, Amiri *et al*., (2010) found that the effect of adding fleawort seed was not significant on the levels of pH and acidity of low-fat yogurt.

Total solids content

The total solids content of the control yogurt sample was 12.78% and total solids content of other treatments ranged from 12.84% to 12.87% (Table - 3). It was expected that WHC would increase and syneresis would decrease relative to increased total solid content, but observations shown in (Table -2) demonstrate that treatments had no significant difference in terms of amounts of total solids content relative to each other or the control sample.

In other words, additions of any of the tested concentrations of β-glucan had no significant difference in the amount of total solids content in yogurt samples at $p<0.05$. Therefore, the difference in syneresis of the yogurt samples was not related to the total solids content. This observation is in

agreement with the results reported by El-Sayed *et al*. (2002) who investigated the effect of xanthan gum and different mixes of guar gum, locust bean gum and carboxymethyl-cellulose (CMC).

Table 3: Effects of different β-glucan concentrations on some physicochemical properties of yogurt samples.

Treatments	pH	Acidity (°d)	T. S (%)	WHC (%)	Firmness (g)
Control Sample	4.44 ^{a}	116.0 ^{a}	12.78^{a}	50.3^{def}	38.7^{cde}
β-glucan.05%	4.42 ^{a}	117.3 ^{a}	12.84^{a}	56.3b^{c}	39^{cde}
β-glucan 1%	4.40 ^{a}	121.0 ^{a}	12.85 ^{a}	64^{a}	41^{bc}
β-glucan 2%	4.42 ^{a}	119.0 ^{a}	12.85 ^{a}	58.3^{b}	48^{a}
β-glucan 3%	4.43 ^{a}	118.0 ^{a}	12.87 ^{a}	58^{b}	41.17^{bc}

Within the same column, the values with the different letter are significantly different ($p<0.05$).

Syneresis

Syneresis is one of the basic defects of yogurt, it concept the contraction of the gel accompanied by the separating out of liquid. which is observed in the form of accumulation of whey on yogurt surface. Syneresis occurs due to shrinkage of the three-dimensional (3D) structure of a protein network, which leads to the reduction of connection power of whey proteins and its exit from the yogurt. Table (4) showed that there were significant difference between syneresis of tested treatments ($p<0.05$). The least amount of syneresis at end storage period (14 day) was observed in yogurts containing 3% β-glucan, while the largest amount of syneresis was observed in yogurt samples containing 0.05% of β-glucan and control yogurt sample, at level 20.20, 21.90 and 23.90 ml/100ml respectively. Syneresis decreased with increased concentration of β-glucan gum because of its role in the formation of a denser gel network in comparison with the control sample and its ability to absorb water.

Domagala *et al*. (2006) examined the effect of gelatin, wheat starch and a mixture of locust bean gum and β-glucan on the syneresis of stirred yogurt. Starch had no significant effect, but the effects of gelatin and the mixture of locust bean gum and β-glucan were significant. In a similar study, Sahan *et al*., (2008) found that syneresis in yogurt decreased with an increased mix of locust bean gum and β-glucan as much as 0.16% and syneresis in yogurt increased in concentrations higher than that. This result is agreed with the results of another related research study by Charles and Carmen (2008) who reported that guar gum decreased syneresis in yogurt. These results are in agreement with those reported by Pérez-chabela *et al*. (2021).

Table.4: Effects of different β-glucan concentrations on Syneresis properties of yogurt samples.

Syneresis Samples	Syneresis (ml/100ml) during the Storage period (days)		
	1	**7**	**14**
Control Sample	28.5±1.49a	24.9±2.10a	23.90±2.01a
β-glucan.05%	26.9±1.49b	23.9±1.25b	21.90±2.01c
β-glucan 1%	25.9±2.01bc	22.9±2.01bc	21.00±2.01c
β-glucan 2%	25.20±2.01c	22.8±2.01c	20.90±2.01d
β-glucan 3%	25.8±2.07bc	23.9±2.02b	20.20±2.02bc

***** Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$).

While syneresis of all yogurt treatments decreased as storage period progressed up to 10 days and then increased at the end of storage period. These results are in agreement with those reported by Pérez-chabela *et al*. (2021).

Water Holding Capability of yogurt samples

Evaluations of WHC (Table-3) showed a significant difference between the yogurt treatments ($p<0.05$). The highest WHC was recorded for the yogurt with 1% β-glucan (64 %) and the least amount for WHC was recorded for yogurt containing 0.05% β-glucan. An addition of xanthan gum at a concentration over 1% decreased WHC to *56*%, but it is higher than control yogurt sample. The results

of this study were consistent with the results reported by Hosseini (2013) upon addition of β-glucan gum to the yogurt.

WHC in β-glucan samples had a significant difference ($p<0.05$) compared to the control sample. Whereas, β-glucan as a hydrocolloids caused a reduction in syneresis in yogurt and an increase in WHC in two ways physical and chemical. Free water is physically trapped and confined within the increased network density, and chemically, the hydrophilic nature of β-glucan facilitate a link with the water molecules as, thus increasing gel water-binding capacity (WBC), where as properties of solidity and elasticity of gel are increasingly with an increased WBC (Lee and Lucey, 2010).

Firmness of texture of yoghurt samples

Texture characteristics measurements are an important criteria for evaluating the quality of yogurt. As can be observed from Table (3), there was a significant difference in texture among the treatments ($p<0.05$). That is to say that the effect of β-glucan addition on firmness of texture of yogurt samples was significant. The addition of β-glucan significantly increased firmness of the yogurt, so that the maximum firmness was observed upon addition of 0.2% β-glucan. β-glucan as a gum either create gel themselves or produce a network of connections among components of the casein network (Mikkelsen *et al.,* 2010). All experiments were repeated triplicate and all obtained data are expressed as an average (Oliveira *et al*., 2001).

Viscosity of yogurt samples

The results in Table (5) showed that fortification of yogurt with β-glucan at different concentrations significantly increased viscosity compared with control yogurt and this increasing was proportional to the fortification ratio. These results might be due to increasing the water holding capacity of β-glucan. Viscosity of all yogurt treatments increased as storage period progressed up to 7 days and then decreased up to the end of storage period. This change could be attributed to the protein rearrangement and protein-protein interactions. Likewise, it is reported that the viscosity of β-glucan in the presence of starch that probably related to the hydrophobicity of the hydrogen-bonded regions of amylase and β-glucan may be responsible for such destabilization (Jirdehi *et al*., 2013). To more elucidating, the β-glucan viscosity profiles at different temperatures are important functional and process parameters for the food industry, because the viscosity of β-glucans is highly responsible for glucose regulation and blood cholesterol reduction in hypercholesterolemia individuals (Wood, 2002), hence it is possible to suggest that this sample of extracted β-glucans has viscosity features for this function. The results for viscosity of β-glucan at 20ºC, where the shear stress versus shear rate curve indicated a pseudo-plastic behavior of β-glucan samples. Evaluation effect of temperature on the β-glucan viscosity indicated that a viscosity of 92.5 Pa s was attained at initial temperature of 5 ºC which was reduced to 0.15 Pa s at final temperature of 80 ºC. Brennan and Cleary (2005) reported that temperature and pH of solution has profound effect on the viscosity of β-glucan extracts. High viscosity of extracted β-glucan could be utilized as alternative of thickening agents in different food industries, or a fat replacer of fermented milk yogurt), as cooled products

Table 5: Effects of different β-glucan concentration on viscosity of yogurt samples.

Viscosity (mPa) Samples	Storage period (days)		
	Fresh	**7 days**	**14 days**
Control Sample	5100 ^{e} ±24.2	5900 ^{e} ±10	5900 ^{e} ±27.01
β-glucan.05%	5200 ^{e} ±29.6	6150 ^{e} ±19.3	5980 ^{e} ±60.8
β-glucan 1%	5360 ^{c} ±33.2	6350 ^{c} ±19.10	6080 ^{c} ±19.10
β-glucan 2%	5490 ^{a} ±29.00	6450 ^{a} ±21.2	6190 ^{a} ±27.01
β-glucan 3%	5520 ^{b} ±5.91	6550 ^{b} ±19.80	6299 ^{b} ±21.7

***** Values (means followed by ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$).

Generally, Barley's β-glucan supplementation in a yogurt was investigated regarding its rheological and chemical characteristics during storage. β-glucans' content incorporation, was applied in four different concentrations as previously described. The current study observed that during storage,

β-glucans' addition improved viscosity, whey separation and texture profile characteristics. Furthermore, properties such as resilience, hardness and cohesiveness were found to be significantly improved according to Aboushanab *et al*. (2018). Additionally, the manufactured yogurt with β-glucan additions displayed higher consistency coefficient (K), and a thicker and compact texture. Their additional ability to act as thickeners, emulsifiers, and stabilizers makes them ideal additives in the dairy, confectionery, meat, pasta and bakery industries Brennan and Cleary (2005).

The use of β-glucan in low-fat formulations significantly increased the viscosity and caused decrease in whey separation and intake of calories. These properties are related to increasing the total solids present in the formulations and the ability of the β-glucan as a fat replacer to entrap water within network of the product.

Antioxidant activities of yoghurt samples.

Antioxidant activity of yoghurt samples are presented in Table (6), there were significant differences in the antioxidant activity of the samples ($P < 0.05$). Addition of β-glucan at different concentrations significantly increased antioxidant activity of yogurt treatments at end of storage period and these increments were proportional to the fortification ratio compared with plain yoghurt. The highest value of antioxidant activity at the end of storage period was found in yoghurt fortified with 3% β -glucan. A similar observation was reported by Pérez-Chabela *et al*. (2021), but antioxidant activity of all yogurt treatments decreased as storage period progressed.

Table 6: Effects of different concentration of β-glucan on RSA% of yogurt samples.

RSA% / Samples	Storage period(days)		
	Fresh	**7 days**	**14 days**
Control Sample	23.40 ^{g} ±1.21	13.30 g ±2.10	10.20 g ±1.31
β-glucan.05%	34.8 ^{f} ±2.00	23. 1 f ±1.24	16.0 f ±1.20
β-glucan 1%	41.0 ^{e} ±2.00	31.0 e ±1.31	23.0±1.35
β-glucan 2%	44.1 ^{c} ±2.11	34.0±1.49c	27.0±1.46c
β-glucan 3%	51.2 ^{a} ±0.10	44.0±1.40a	40.3±1.41a

* Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$).

On the other hand**,** the concentration required to obtain 50% DPPH radical scavenging activity (IC_{50}) for the yoghurt incorporated with β-glucan extract was 2g/ L. The impact of antioxidants on DPPH radical scavenging is considered to be due to their ability of hydrogen-donating. Some antioxidant activities of yoghurt and other fermented milks are related to bioactive peptides released during fermentation and supplementation also during storage periods. The bioactive peptide showed antioxidant activity *in-vivo* and *in-vitro* (Awad *et al*., 2016). The other bioactive compounds in milk, such as protein, vitamins and functional groups of β-glucan (hydroxyl radicals as described in Fig.1). Also, have good antioxidant activities. The DPPH radical scavenging rate was increased with the increasing concentrations of exopolysaccharides (EPS) (Zhu *et al*., 2018). Moreover, You Guo *et al*. (2009) reported that purslane polysaccharides showed a good effect on scavenging of hydroxyl radicals, DPPH, superoxide anion and nitric oxide in a dose-dependent manner. The antioxidant activity which observed in this study may be attributed to the combined effect of bioactive compounds in β-glucan extract and the action of lactic acid bacteria (Papadimitriou *et al*., 2007). Phenolic contents and antioxidant activity of all yogurt treatments decreased as storage period progressed.

Color of yogurt samples are presented in Table (7) showed that the luminance (L^*) of β-glucan yogurt significantly increased with the increase of the amount of β-glucan from 0.5 to 2%, but it was significantly lower than that of the plain yogurt. It is suggested to be due to the reduction of fat content. The red color (a^*) of yogurt with 1% and 2% of β-glucan was similar to that of plain yogurt. Thus, 1% and 2% β-glucan can improve the red color of yogurt. While the yellowness (b^*) of all β-glucan samples remains lower than that of the plain yogurt as showed in Fig. (8 A,B and C). On the other hand, no studies had been established so far about the effect of β-glucan on the color of yogurt.

Table 7: Color (*L* *: luminance, *a* *: red value, *b* *: yellowness) of yogurt with different proportions of β-glucan (0.5%, 1%, 2% and 3%) in comparison with the plain yogurt.

Sample	Color		
	L*	***a****	***b****
Control Sample	$85.43^{e} \pm 0.01$	$-5.71^{c} \pm 0.03$	$7.24^{d} \pm 0.03$
β-glucan.05%	$82.34^{b} \pm 0.04$	$-6.01^{a} \pm 0.03$	$4.24^{a} \pm 0.03$
β-glucan 1%	$82.57^{c} \pm 0.01$	$-5.70^{c} \pm 0.05$	$6.05^{c} \pm 0.04$
β-glucan 2%	$82.95^{d} \pm 0.01$	$-5.72^{c} \pm 0.04$	$6.03^{b} \pm 0.04$
β-glucan 3%	$82.19^{a} \pm 0.06$	$-6.01^{b} \pm 0.03$	$4.26^{a} \pm 0.02$

Data are expressed as: Mean value ± standard deviation, Mean values followed by the same letter in each column are not significantly different at P ≤0.05.

Microbiological Evaluation of Different Types of β-glucan Yogurt and plain yogurt

Table (8) showed the differences in total bacterial counts of plain and b-glucan yogurt during storage period. The results indicated that total bacterial count gradually decreased as storage period progressed until the end of storage period. Yogurt treatments fortified b-glucan at different concentrations had the lowest counts of total bacterial count. Total bacterial count decreased, also, with increasing the concentration.

Streptococcus thermophilus and *Lactobacillus bulgaricus* counts gradually increased in all treatments up to 7 days form storage and then decreased at the end of storage period. Yogurt treatments fortified with β-glucan at different concentrations had the lowest *Streptococcus thermophilus and Lactobacillus bulgaricus* counts. Fortification of yogurt with β-glucan decreased the counts of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* compared to control yogurt and this may be due to high antibacterial properties of β-glucan. The general trend of these results agreed with those reported by Habib *et al*. (2018). In addition, all treatments had more probiotic bacteria than the minimum requirement (Table 8). The results of this study are consistent with the study by Paseephol *et al*. (2008).

On the other hand, the mean numbers of total LAB from yogurt culture in all yogurts were between 10^7 CFU.g^{-1}. Similar results were obtained by Damin *et al*. (2009) for yogurts with different levels of supplementation. Probiotic yogurt is a classic example of a functional food. Special types of yogurts are often manufactured for dietetic and/or therapeutic purposes and are known as bio-yoghurts (Parvez *et al*., 2006). The primary probiotic bacteria associated with dairy products are *Lactobacillus acidophilus, Lactobacillus casei* and *Bifidobacteria* which were included in the group of lactic acid bacteria but not all lactic acid bacteria is probiotics. In order to provide certain health benefits to humans as mentioned and elucidated in (Table - 8 and Fig-9) the count of probiotics bacteria in fermented milk should be 10^6 colony forming units (CFU)/g at the end of the shelf life of a product (Achanta *et al*., 2007; Ahmadi, 2010). It seems reasonable to assume that the beneficial effects of probiotics bacteria can be expected only when viable cells are ingested.

Table 8: Total bacteria (TBC), *Streptococcus thermophilus* and *Lactobacillus bulgaricus* counts of different concentration of β-glucan during storage period.

Sample	***St. thermophiles (cfu 10^7)***			***L. Bulgaricus (cfu 10^7)***			**TBC (cfu 10^7)**		
Counts	**Storage period (days)**			**Storage period (days)**			**Storage period (days)**		
	fresh	**7**	**14**	**fresh**	**7**	**14**	**fresh**	**7**	**14**
Control Sample	53	69	60	27	64	83	101	57	31
β-glucan.05%	57	66	48	29	73	86	106	66	40
β-glucan 1%	45	64	41	25	67	77	96	48	30
β-glucan 2%	36	55	30	18	55	65	89	47	25
β-glucan 3%	37	55	33	25	55	61	85	49	20

Sensory evaluation

Results in Table 9 showed that there was variation between control and fortified yogurt in sensory attributes. Control yogurt had the lowest values. Addition of β-glucan improved the organoleptic properties of fortified yogurt. The highest mean value was related to sample containing 3% β-glucan.

The organoleptic properties of all yogurt treatments decreased as storage period progressed. A similar observation was found by Al-Hamdani *et al*. (2015).

Sensory evaluations showed a significant difference between the yoghurt samples ($p<0.05$)

As can be observed from (Table 9), the highest score was observed in samples containing 2 and 3% β-glucan, with level of 94 total score, and a significant difference with the control sample in the sensory evaluation. The lowest score (87 and 88) was observed in the samples containing 0.05% β-glucan and control yoghurt sample, respectively (Table-9 and Fig – 10 D). Amiri *et al*. (2010) used β-glucan and inulin as fat substitutes. Then, yogurt syneresis reduced and rheological and textural characteristics of the yogurt noticeably improved. The texture of yogurt improved with addition of 1% β-glucan, but a concentration of more than 2% was required in order to actualize the effect of β-glucan and inulin. On the other hand, the higher β-glucans' concentration (2–3%) resulted in the higher acceptability On the other hand, the higher β-glucans concentration (2–3%) resulted in the higher acceptability, similarly with results of Kaur and Riar (2020). Sensory analysis conducted on the samples illustrated that the inclusion of β-glucan-based fat replacers could be successfully utilized to mimic full-fat products. However, this work extends the potential utilization of β-glucan into the dairy industry situation in terms of both human nutrition and product texture. According to evaluations of the juries, the best results were obtained by adding 2 and 3% concentration of β-glucan. Since additions of β-glucan improved the texture and reduced syneresis of the samples compared to the control sample.

Table 9: Sensory evaluations of different concentration b-glucan yogurt and plain samples during storage period

Samples	Appearance (10)			Body and Texture (30)			Flavour (60)			Total (100)		
	Storage period (days)			Storage period (days)			Storage period (days)			Storage period (days)		
	1	7	14	1	7	14	1	7	14	1	7	14
Control Sample	8	8	7	28	28	26	57	55	54	93±0.33 g	91±0.35 g	87±0.43 g
β-glucan.0.5%	8	8	7	28	28	26	57	57	55	93±0.40 e	95±2.05 e	88 ±0.35 e
β-glucan 1%	8	9	8	29	29	27	58	58	56	95±0.34c	96±0.29 c	91 ±0.34c
β-glucan 2%	9	9	8	29	29	28	58	58	58	96±0.30 c	96±0.36 a	94 ±0.33 a
β-glucan 3%	9	8	8	30	29	28	59	58	58	98±0.40 a	95±0.35 f	94 ±0.34 f

* Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$).

Conclusions

Nowadays, consumers are demanding for foods with increasingly properties, such as pleasant flavor, low-calorie value or low fat content, and benefic health effects. Within this context, we have been trying to offer products with improve flavor and appearance. In addition, functional dairy products offer requirements, benefits to health that are strengthened by the addition of probiotics as well as by certain types of soluble fibers known as prebiotic.

Therefore, the results of the current study showed that tested β-glucan had a somewhat significant effect on pH, titratable acidity, total solids content, and probiotics bacteria counts of yogurt samples, but β-glucan showed a more porous and spongy structure reflected on characteristics of product, were effective on syneresis, WHC, stiffness of texture, and sensory characteristics of the yogurt samples. The use of β-glucan are highly recommended for low-fat yogurt production bioyogurt as functional food and nutricetical in aging, heart diseases and infant stage.

On the other hand, adding β-glucan had affect a somewhat amounts of probiotics bacteria but remained at sufficient levels (>6 log cfu/g) for up to 14 days. We need further studies of these points and take wider look the use of barley β-glucan in the yoghurt industry.

Enrichment of barley β-Glucan in the manufacture of yogurt is advantageous, with a recommended daily intake of 2, 5-3,0 g for adult's diseases. Therefore, yoghurt containing β-glucan could be an innovative healthy product for enhancing β-glucan consumption in the diet.

In the main, β-Glucan was manifested to be successfully used as a functional ingredient and to improve the quality of non-or low-fat milk yoghurt. Barley β-glucan shows a great potential for use as a thickener, water-holding agent, oil-binding agent or emulsifying stabilizer in food products such as soups, sauces, desserts and salad dressings. However, its performance in food systems needs to be tested.

Overall, β-Glucan as bioactive ingredients could be used as alternative particulate (fat replacer) filler enriching body with nutrients decreasing the risk of many diseases and enhancing milk gel network strength and diminishing product defects such as whey loss. The present study determined that adding β-glucan did affect had a somewhat amounts of probiotics bacteria according to standardization legalization. Consumption of foods with β-glucans has been proven to contribute to human health with many beneficial properties, which suggests that they could have been potentiated by the reciprocal synergistic effects of microorganisms in complex mixture.

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