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THE USE OF INULIN AS A DIETARY FIBER IN THE PRODUCTION OF SYNBIOTIC UF-SOFT CHEESE

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ABSTRACT

Supplementation of low fat UF- soft cheese manufactured from UF–milk retentate with inulin -as a source of dietary fiber- and probiotic ABT-2 culture was investigated. Inulin was used at levels of 1, 3, 5 and 7% of inulin (IN1, IN3, IN5 and 1N7, respectively). Resultant cheese from different treatments was analyzed for chemical, physical, microbiological, rheological and sensory properties when fresh and after 10, 20 and 30 days of storage at 7°C. The results revealed that the addition of inulin mostly increased moisture and ash content in the stored cheese, WSN/TN and acidity and decreased protein and pH of cheeses compared with the control without inulin. During storage, titratable acidity and WSN/TN content increased and pH values decreased in all treatments including control. Addition of inulin to probiotic UF-soft cheese significantly increased the viability of *Lb. acidophilus* and *Bifidobacterium BB12* at 20 days of storage then their counts sharply declined which was statistically significant (P<0.05) from initial counts. However, addition of inulin at 5 and 7% to milk retentate was more effective than the addition of 1 and 3% during the storage period. Rheological characteristics of the texture (hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness) were significantly lower in most cheeses samples made with inulin. The sensory evaluation showed that the pre-mentioned cheese with 7% inulin ranked the maximum scores for flavour, body & texture and the general appearance with an overall score of 89.00 out of 100 points. The received data indicated that, using inulin at 5 and 7% was good enough to compete with control with fat. So, it can be recommended to use such substances at the recorded levels and the prebiotics in preparing synbiotic UF soft cheese.
Keywords: Probiotics, inulin, UF-soft cheese

INTRODUCTION

Current research tends to use prebiotics and probiotics in the development of functional foods called "synbiotic food", which are those products that contain both probiotic microorganisms and prebiotic ingredients (Holzapfel & Schil-linger, 2002). The probiotics are live microorganisms which exert a beneficial effect on the health of the host when they are administered in adequate quantities (FAO/WHO, 2002) while prebiotics are non-digestible food ingredients, whose purpose is to serve as food for the probiotic microorganism and thus increase their survival chances and implantation in the host intestinal tract. Inulin is a fructooligosaccharide containing β (2,1) linked fructosyl residues, typically terminating with a glucose molecule. Inulin is a water-soluble dietary fiber and a prebiotic, the food source for the beneficial gut microflora probiotics. Furthermore, inulin can be employed in foods as a low-calorie sweetener, fat substitute and texture modifier (Meyer, *et al.,* 2011).

The incorporation of inulin, in foods is known to reduce the risk of colon cancer, diabetes, obesity, and cardiovascular diseases in human beings ((Miremadi and Shah, 2012). The functionality of the carbohydrate-based fat substitutes like inulin is established in relation to their ability to increase viscosity, form gels, provide mouth feel, texture and to increase water-holding capacity.

From the technological point of view, inulin as gelling performance is a perfect ingredient to replace fat due to its ability to form a gel or cream, resulting in an excellent fat-like texture. Inulin brings also creaminess; body and mouth feel. For prevention of syneresis, inulin especially long chain has an excellent water binding capacity which prevents syneresis in spreads and fresh cheeses. Inulin has a good spreadability, mouthful, flavour enhancers and stabilizers (Vajiheh, *et al.,* 2012). Using inulin to reduce fat allows nutrition claims like 'reduced fat/ calories' or 'light'. On the other hand inulin as a dietary fiber acts as prebiotic, which are not digested by human enzymes and reach colon where they stimulate the growth and/or activity of one or a limited number of bacteria, thus improving the host's gut health (Meyer, *et al.,* 2011).

On other hand, cheese has a good potential for delivery of probiotic microorganisms into the human intestine due to its specific chemical and physical characteristics compared to fermented milks such as higher pH and lower acidity, higher buffering capacity, greater fat content, higher nutrient availability, lower oxygen content, and denser matrix of the texture (Karimi *, et al.,* 2011). In addition, a large variety of cheese types all over the world, consumption of cheese by everybody in their long term diet, as well as the nutritional value of cheese have resulted in regular market growth for probiotic cheeses. To be considered to offer probiotic health benefits, probiotics must remain viable in food products above a threshold level (e.g., 10^6cfu /g) until the time of consumption, without adversely altering sensory attributes (Karimi *, et al.,* 2011). Inulin has been successfully incorporated as a prebiotic in cheese (Holzapfel and Schillinger, 2002, Effat *et al***.,** 2012; Alnemr, *et al.,* 2013) and its synbiotic, effect with probiotic has been thoroughly studied (Buriti *et al.,* 2007; Rodrigues, *et al.,* 2011; Azambuja, *et al* ., 2013; Juan, *et al.,* 2013). It is cohesive structure, higher pH and fat content offer cheeses additional protection to the probiotic bacteria during its passage through the gastrointestinal tract (Cruz, *et al.,* 2009). Indeed, several researches concerning the development of probiotic cheeses were given in the literature (Gomes *et al.* 2011; Vajiheh *et al.,* (2012); Alves, *et al.,* 2013; Salvatore, *et al.,* 2014).

In Egypt, soft cheese is the most commonly consumed and recent advances in nutrition science have highlighted the contribution of UF soft cheese to nutrition and health, owing to inclusion of whey proteins into the cheese matrix; they act as a cysteine delivery system to inhibit the tumor growth and to improve the immune system in general (Kamau and Lu, 2011). Also, recently there have been a large increase in the demand for reduced fat products, resulting in numerous industries choosing to produce sorts of cheese with low reduced fat content (Koca and Metin, 2004).

Therefore, this research aimed to evaluate the adequacy of UF-soft cheese as a food matrix for supplementation with a mixed ABT probiotic culture and a prebiotic ingredient (inulin). The physical–chemical parameters, viability of a mixed ABT probiotic culture as well as instrumental texture profile and sensorial properties of cheese were evaluated during refrigerated storage for different intervals.

MATERIALS AND METHODS

Materials :

Probiotic Culture; DVS-Probio-Tec™ ABT-2 (*Lactobacillus acidophilus-5, Bifidobacterium BB-12,* and *Str. thermophilus*) as a probiotic culture was obtained from Chr. Hansen Laboratories, Copenhagen, Denmark. Inulin was obtained from AnuMed-Intl, A Biomed Company, Phoenix, USA. Fine cooking salt produced by EL-Naser Company and liquid rennet were obtained from the local market. UF- milk retentate samples (2 and 12% fat content) were obtained from dairy processing unit, Animal Production Res. Inst., Agric. Res. center, Min. of Agric., Egypt.

Production of synbiotic UF- soft Cheese:

Low- fat milk retentate used as it without standardization was divided into five equal portions. One batch had no inulin was served as a control (LFC). The latter batches were fortified with inulin at the rate of 1, 3, 5 or 7% (w/w) to give IN1, IN3, IN5 and IN7, respectively and standardized fat milk retentate (12% fat) without inulin was used as positive control, (FFC). UF-soft cheese was made according to the method described by Renner and Abd El-Salam (1991). All retentate batches were heated to 75°C, cooled to 38°C, inoculated with ABT-2 starter culture (0.04%) and incubated until pH 6.4. Then, salt (2%) and calcium chloride (0.02%) were added to milk retentate with sufficient quantity of rennet. The pre-cheese was immediately filled into plastic containers and incubated at the same temperature (38°C) to complete coagulation within 40 min. At this point the containers were removed from the incubator and kept at refrigerator temperature (7°C) for 30days. Two replicates were carried out from each treatment.

Analytical procedures

The physic-chemical, microbiological, textural and organoleptic analyses were carried out at fresh, 10, 20 and 30 days of refrigerated storage. Moisture, ash, total nitrogen and soluble nitrogen (using semi – micro-kjeldahl method) contents of soft cheese samples were determined according to AOAC (2000). The protein content was obtained by multiplying the percentage of TN by 6.38. The pH was measured using a digital pH meter (HANNA, instrument, Italy).

For the microbiological analyses, 1 g of cheese was transferred into a stomacher containing 9 mL of sterile 0.1% w/v peptone water. Further dilutions were made from this original dilution and the quantification of microbial counts was carried out using the pour plate technique. *Str. thermophilus* was enumerated in M17 agar and aerobic incubation for 37°C after 48 h, *Bifidobacterium BB12* was enumerated using deMan, Rogosa -

Sharpe Agar (MRS), agar supplemented with glucose, lithium chloride and cysteine, and *Lb. acidophilus* was enumerated using MRS Basal agar supplemented with maltose. These media were previously reported by Tharmaraj and Shah (2003). Plates containing 25 to 250 colonies were enumerated and recorded as colony forming units (CFU) per gram of sample.

Textural properties of cheese were evaluated using a TMS-Pro Texture Analyzer (Food Technology Corp., U.S.A.). The cheeses were cut into cubes (3×3×3 cm) and stored overnight at 7˚C before analysis. In the experiment, samples were compressed to 50% of their original height at the speed of 10 mm/sec. The flat probe used was 30 mm in dia. After pausing for 5sec, the probe ran upward at the speed of 10 mm/sec until returned to the original height. Hardness (N), adhesiveness (J), springiness (mm), cohesiveness (ratio), gumminess (N) and chewiness (J) were evaluated in triplicate as described by Szczesniak, *et al.,* (1963) and Bourne, (1978).

Cheese samples were evaluated for flavour (50 points), body and texture (40 points) and appearance (10) points by 7 panelists according to Bodyfelt, *et al.,* (1988).

Statistical analysis was carried out using SPSS program Inc. software (version 10.0; SPSS Inc., Chicago, IL) and the statistically different treatments were determined by the DUNCAN's Multiple Rage tests (SPSS, 1998). All data are presented as average ± SE

RESULTS AND DISCUSSION

The moisture content of synbiotic UF- soft cheeses made with adding inulin (1, 3, 5 and 7 %) with along probiotic ABT-2 culture was different as compared with the control probiotic low fat soft cheese, LFC (Table 1). In fresh cheese, the differences in moisture due to amount of inulin added were significant, whereas in the different old cheese samples the differences in this respect were significant. The changes in the moisture due to storage were not identical. This might be due to the shrinkage of the curd as a result of acid development which helps to expel the whey from the cheese mass. Nearly similar results were given by Effat *et al.,* (2012).

The moisture content of probiotic low fat UF soft cheeses made with inulin was significantly higher than those cheese without inulin (LFC) (P<0.05). The same was found by Zalazar *et al.,* (2002). One of the most important strategies for using fat replacers like inulin is the increase of water binding capacity of the cheese matrix, since water can bind directly to fat replacers which can interfere with the shrinkage of the casein matrix. Buriti *et al.* (2007) and Vajiheh *et al.,* (2012) showed that commercial inulin, at a proportion of 8%, might been applied in the manufacture of synbiotic fresh cream cheese supplemented with *Str. thermophilus* and *Lb. paracasei*. Koca and Metin (2004) stated that addition of fat replacer in general to low-fat cheese increased moisture content and yield of cheese.

Ash content of cheese was significantly affected (P<0.05) by inulin especially when added at higher concentration. The control cheese had almost lower values of ash as compared with those cheese made with inulin.

However, it may be of interest to note that cheese from IN5 treatment had always the maximum ash content among all samples of the same age. The opposite was recorded for the LFC and FFC which showed the lowest ash content at any given cheese age suggesting that fat from one-side and inulin as a fat replacer from the other- side had pronounced effect on ash content of the resultant soft cheese. Concerning impact of storage, the 30 days old inulin treated cheese had significant lower ash content than the corresponding fresh samples.

Concerning the protein content (Table 1) it was noticed that the higher amounts of inulin added significantly decreased the protein content of the resultant cheese. The lowest values were recorded in such samples at the end of storage period. However prolongation of storage period to 30days had a significant decreasing impact in this respect.

Table (1): Moisture, ash and protein contents of synbiotic UF soft cheese made with probiotic ABT-2 culture and different level of inulin during storage period

Treatments	Storage/ day			
	Fresh	**10**	**20**	**30**
	Moisture, %			
FFC	69.54±0.00^{Cd}	66.91±0.16 ^{Bb}	66.58±0.05^{Ba}	68.26±0.07 ^{Dc}
LFC	63.91±0.22^{Aa}	61.89±0.25^{Aa}	62.26±0.41^{Aa}	62.04±0.13^{Aa}
IN1	67.78±1.03^{Ba}	69.29±0.19^{Da}	68.44±0.21^{CDa}	67.89±0.09 ^{Ca}
IN3	67.02±0.16^{Ba}	68.01±0.03^{Ca}	67.88±0.55^{Ca}	67.67±0.00^{BCa}
IN5	67.79±0.09 ^{Bb}	66.93±0.14^{Ba}	67.78±0.14^{Cb}	67.44±0.10 ^{Bb}
IN7	67.90±0.06^{Ba}	67.69±0.06 ^{Ca}	69.03±0.36^{Db}	68.96±0.16 ^{Eb}
	Ash, % (dry basis)			
FFC	9.14±0.00^{Aa}	8.91±0.34^{Aa}	9.05±0.09^{Aa}	9.07±0.00^{Aa}
LFC	10.17±0.08 ^{Ba}	10.06±0.03^{Ba}	10.07±0.43^{Ba}	10.27±0.18^{Ca}
IN1	10.46±0.03 ^{Cc}	10.26±0.13^{Bbc}	10.09±0.06^{Bab}	9.94±0.02^{Ba}
IN3	10.44±0.05^{Cc}	10.10±0.01^{Bb}	9.81±0.06^{Ba}	9.91±0.01^{Ba}
IN5	12.52±0.02^{Ec}	11.62±0.06^{Cb}	11.65±0.02^{Cb}	11.28±0.05^{Da}
IN7	11.02±0.06 ^{Cc}	11.38±0.02^{Cd}	10.80±0.01 ^{Db}	10.34±0.01^{Ca}
	Protein, % (dry basis)			
FFC	34.19±0.02^{Ab}	33.64±0.48^{Ab}	32.10±1.59^{Aab}	30.46±0.01^{Aa}
LFC	49.46±0.21^{Db}	49.47±0.39^{Eb}	49.42±0.13^{Db}	47.54±0.24^{Ca}
IN1	49.64±0.18 ^{Db}	49.53±0.19^{Eb}	47.18±1.04^{CDa}	47.49±0.33 ^{Ca}
IN3	49.68±0.15^{Db}	47.57±0.24^{Da}	47.92±0.34^{Da}	47.40±0.10 ^{Ca}
IN5	46.45±0.60^{Cb}	45.52±0.32^{Cb}	45.17±0.52^{BCab}	43.63±0.58^{Ba}
IN7	42.24±0.06^{Ba}	43.91±0.16^{Bb}	44.40±0.49^{Bb}	42.71±0.38^{Ba}

Means (±SE) with unlike capital or small superscripts within column (treatments) and row (storage period), respectively are significantly different (*P*<0.05). IN1, IN3, IN5 and IN7 = cheese made from low fat UF milk with 1, 3, 5and 7% inulin (w/w).

The changes in the titratable acidity and pH values during storage of cheese at 7°C are given in Table (2). It is obvious that the acidity values of UF soft cheese with inulin were higher in general than those of the control cheese either when fresh or during the storage period whereas, increasing the amount of inulin seems to have no significant impact in this respect. Mehanna *et al.* (2002) and Elewa, *et al.,* (2009) mentioned that the

development of acidity during the refrigeration period is a direct response for converting the residual lactose in cheese into lactic acid by the available microflora. UF-soft stored cheese manufactured without inulin had the lowest acidity value.

The changes in pH of synbiotic UF soft cheese followed an opposite trend to acidity. Table (2) shows that the control LFC had always higher pH than inulin –treated cheese samples. IN7- treated samples had the lowest pH values at any given storage time. Moreover, statistical analysis revealed that the pH of synbiotic white soft cheeses was almost significantly (P<0.05) affected by the refrigeration period and different treatments. However, probiotic low fat UF soft cheese made with 7% inulin had the lowest pH values. The obtained results are in harmony with those obtained by Magdoub, *et al.* (1995), who reported that the decrease in pH values may be due to the convert of residual lactose in cheese to lactic acid and free fatty acid which had developed in the cheese at the end of storage period. Besides, Fooks, *et al.* (1999) reported that the decrease in pH values may be due to short chain fatty acids which produced in varying quantities as metabolic end product of the probiotic bacteria. The influence of fibers on the activity of starter cultures and pH value of the product depend on the type of bacteria used in dairy products, as well as the type of the prebiotic used, especially on the length of their chains (Aryana and McGrew, 2007).

Table (2): Changes in acidity, pH and WSN/TN of synbiotic UF soft cheese made with probiotic ABT-2 culture and inulin during storage period.

Treatments	Storage/ day			
	Fresh	10	20	30
	Acidity%			
FFC	0.20±0.01^{Aa}	0.21±0.01^{Aab}	0.24±0.01^{Abc}	0.25±0.00^{Ac}
LFC	0.26±0.01^{Ba}	0.28±0.02^{Bab}	0.29±0.01^{Bab}	0.31±0.01^{Bb}
IN1	0.22±0.01^{Aa}	0.29±0.02^{Bb}	0.33±0.00^{BCc}	0.37±0.01^{Cc}
IN3	0.25±0.01^{Ba}	0.32±0.01^{Bb}	0.38±0.01^{Cc}	0.39±0.00^{CDc}
IN5	0.25±0.01^{Ba}	0.32±0.02^{Bab}	0.37±0.04^{Cbc}	0.42±0.02^{Dc}
IN7	0.26±0.01^{Ba}	0.32±0.01^{Bb}	0.36±0.01^{Cb}	0.53±0.02^{Ec}
	pH			
FFC	6.20 ±0.04^{Cc}	6.06±0.05^{BCbc}	5.92±0.05^{Cab}	5.86±0.05^{Ca}
LFC	6.22±0.03^{Cc}	6.15±0.02^{Cc}	6.00±0.01^{Cb}	5.91±0.02^{Ca}
IN1	6.11±0.01^{BCd}	5.91±0.03^{Ac}	5.72±0.07^{Bb}	5.43±0.08^{Ba}
IN3	6.01±0.06^{ABb}	5.94±0.03^{ABb}	5.75±0.05^{Ba}	5.88±0.02^{Ca}
IN5	6.12±0.01^{Bcb}	5.90±0.05^{Ac}	5.72±0.06^{Bb}	5.49±0.07^{Ba}
IN7	5.98±0.05^{Ad}	5.81±0.06^{Ac}	5.38±0.03^{Ab}	5.17±0.05^{Aa}
	WSN /TN (%)			
FFC	14.83±0.24^{Ca}	15.94±0.47^{Eab}	18.68±0.95^{Cb}	21.71±1.39^{Bc}
LFC	11.15±0.33^{Aa}	12.08±0.05^{Aa}	13.52±0.23^{Aa}	17.07±1.54^{Ab}
IN1	11.19±0.31^{Aa}	13.56±0.60^{ABb}	16.44±0.37^{Bc}	16.73±0.22^{Ac}
IN3	11.03±0.36^{Aa}	14.26±0.28^{BCb}	16.60±0.55^{Bc}	17.21±0.70^{Ac}
IN5	13.22±0.22^{Ba}	14.27±0.41^{BCa}	17.99±0.69^{BCb}	20.36±0.25^{Bc}
IN7	16.00±0.76^{Ca}	16.50±1.29^{Da}	19.49±0.68^{Cb}	22.30±0.73^{Bc}

*** See legend to Table (1) for details.**

Table 2 shows water soluble nitrogen/ total nitrogen (WSN/TN %) content of probiotic UF soft cheeses made with different level of inulin. The recorded values due to IN5 and IN7 treatments were higher when compared

with the values due to IN1 and IN3 treatments or even than that of LFC. The differences in this respect were almost significant. This was true at any given storage time. The changes in this respect due to storage were also significant at certain storage intervals, but in an increase in general. These results coincide with those obtained by Elewa *et al.,* (2009) and Effat *et al.,* (2012), who reported that the SN contents of white soft cheeses made with probiotics increased at the end of storage period, whereas Shehata *et al.* (2001) attributed such increase, to the enzymes released by starter cultures during storage.

Role of the probiotic bacteria in such proteolysis may be of some interest, Ong *et al.* (2007) claimed that Bifidobacterium sp. was a weak proteolytic bacterium, when compared with strains of Lactobacillus. Several authors (e.g. Gomes, *et al.,* 1998; Gomes, *et al.,* 1999; Cruz, *et al.,* 2009) have shown that incorporation of probiotic bacteria in cheese did not generally affect primary proteolysis which is brought about by residual coagulant or even milk plasmin; yet it affected secondary proteolysis, via increasing the total free amino acid content which may indirectly contribute to cheese flavor and/or aroma.

Viable counts of *Str. thermophilus, Lb. acidophilus* and *Bifidobacterium BB-12* (Log cfu/g) in cheese are shown in Table (3). Data indicated that, during the first 10 days of the refrigeration storage, it could be perceive that their counts increased, in general then declined gradually reaching the minimum counts at the end of storage. Statistical analysis revealed that addition of inulin and/or the storage period significantly affected (P<0.05) *Lb. acidophilus* and *Bifidobacterium BB-12* counts in most cheeses. *Str. thermophilus* counts in all cheese treatments were insignificantly affected (P>0.05), either when fresh or during the refrigeration storage period with using inulin. Higher counts of *Bifidobacerium BB-12* could be attributed to the ability of genus Lactobacillus to survive at high acidity and the presence of inulin as compared with counts of *Lb. acidophilus*. In general it could be noticed that cheese made with inulin had higher *Bifidobacerium BB-12* counts as compared with the corresponding counts of cheese made without inulin. It could be also seen that counts of all lactic acid strains increased during the refrigeration period reaching the maximum counts after 10 days, and then decreased with prolonging the storage period.

However, the counts of bifidobacteria in all treatments were higher than those recommended in the literature (10^6cfu/g) to get the desired therapeutic effects. These results are in agreement with those obtained by Elewa *et al.,* (2009) and Effat *et al.,* (2012), who reported that addition of prebiotics most probably improved the growth and viable counts of probiotics. On the other hand, *Lb. acidophilus* showed a sharp fall in viability during the storage period studied (Table 3), among the possible reasons given was the negative interaction between this probiotic culture and the lactic cultures added (Joseph *et al*. 1998; Vinderola *et al.* 2002) However, it is possible that this interaction is dependent on the strain and the food matrix used as the vehicle for supplementation.

Table (3): Viability of *Str. thermophilus*, *Lb. acidophilus* and *Bifidobacterium BB12* of synbiotic UF soft cheese made with probiotic ABT-2 culture and different levels of inulin during the cold storage

Treatments	Fresh	10days	20 days	30 days
	***Str . thermophilus* (log cfu/g)**			
FFC	10.49± 0.17^{Ba}	10.37± 0.18^{Aa}	10.66± 0.14^{Ba}	10.74± 0.12^{Ca}
LFC	9.82± 0.16^{ABa}	10.13± 0.27^{Aa}	10.19± 0.28^{ABa}	10.02± 0.27^{BCa}
IN1	9.36± 0.18^{Aab}	9.95± 0.24^{Ab}	9.39± 0.23^{Aab}	9.00± 0.05^{Aa}
IN3	9.25 ± 0.06^{Aa}	10.33± 0.17^{Ab}	9.60± 0.29^{Aa}	9.50± 0.26^{ABa}
IN5	9.64 ± 0.45^{ABa}	10.11± 0.31^{Aa}	9.90± 0.25^{ABa}	9.16± 0.24^{Aa}
IN7	9.84± 0.37^{ABa}	10.01± 0.31^{Aa}	9.98± 0.31^{ABa}	9.69± 0.41^{ABa}
	***Lb. acidophilus* (log cfu/g)**			
FFC	8.58 ±0.05^{Dc}	8.45±0.08^{Bc}	7.48±0.16^{BCb}	6.04±0.14^{ABa}
LFC	7.38±0.13 ^{Ac}	7.51±0.18 ^{Ac}	6.49±0.14^{Ab}	5.66±0.12^{Aa}
IN1	7.67±0.13^{ABb}	7.79±0.22^{ABb}	7.29±0.20^{BCb}	6.50±0.14^{BCa}
IN3	7.95±0.20^{ABcbc}	8.29±0.18^{Bc}	7.62±0.21^{CDb}	6.59±0.18^{Ca}
IN5	8.40±0.18^{CDb}	8.40±0.31^{Bb}	8.01±0.16^{Db}	7.22±0.17^{Da}
IN7	8.08±0.31^{BCDb}	7.95±0.30^{Bb}	6.98±0.12^{ABa}	6.62±0.19^{Ca}
	***Bifidobacterium BB12* (log cfu/g)**			
FFC	7.80 ±0.18^{Bbc}	8.25 ±0.13^{Bc}	7.38±0.19^{Bb}	6.38±0.19^{Ba}
LFC	6.89 ±0.13 ^{Ac}	6.36 ±0.07^{Ab}	6.55±0.17^{Abc}	5.55±0.17^{Aa}
IN1	8.47 ±0.25^{BCab}	8.85 ±0.34^{Bb}	8.85±0.28^{Cb}	7.86±0.27 ^{Ca}
IN3	8.52±0.24^{BCab}	9.10 ±0.45^{BCb}	9.08±0.34^{Cb}	7.72±0.48 ^{Ca}
IN5	9.08 ±0.32^{Cb}	9.90 ±0.32^{Cc}	9.19±0.06^{Cb}	8.19±0.06 ^{Ca}
IN7	8.74 ±0.37^{Ca}	9.20 ±0.43^{BCa}	9.07±0.44^{Ca}	8.32±0.24 ^{Ca}

*** See legend to Table (1) for details.**

Concerning the impact of inulin, Oliveira, *et al.,* (2009) observed an effect of adding inulin with concentrations varying from 0.44% to 3% to fermented milk on the counts of *B. animalis Bb-12* after 30 days of storage, and found no effect of the prebiotic on *Lb. acidophilus La-5.* Buriti, *et al.*, (2007) found that the addition of inulin did not promote the growth and viability of both *Lb. paracasei*, and *Str. thermophilus*. When the sugar and fructan contents in synbiotic cheese were analyzed, it was found that glucose and galactose contents were significantly (P<0.05) reduced and increased respectively, as some strains of *Str. thermophilus* were not able to metabolize galactose; while both *Str. thermophilus* and *Lb. paracasei* can metabolize glucose. This indicated that the inulin was not utilized nor fermented by *S. thermophilus* and *L. paracasei subsp. paracasei* as the ability to ferment inulin is strain dependent. The researchers thus concluded that although inulin was not used as a prebiotic by probiotic *Lb. paracasei subsp. paracasei*. However, the viable counts for the *Bifidobacterium BB-12* were above 7 log CFU/g throughout storage period, and more than 7% of inulin remained within the cheese, which was sufficient as a synbiotic product.

Textural parameters of probiotic UF- soft cheeses made with different levels of inulin are tabulated in Table (4). Hardness decreased from 792.00 (N) in fresh control cheese (LFC) to 519.63 and 420.88 (N) in fresh cheeses made with 5 and 7% inulin respectively. Such values were significantly (P< 0.05) lower than those of FFC. All values decreased throughout storage

period and this is in agreement with the previous studies (Dabour, *et al.,* 2006**;** Alnemr, *et al.,* 2013; Juan, *et al.,* 2013**)**. Using inulin in IN1, IN3, IN5 and IN7 treatment instead of fat significantly decreased hardness which could be attributed to the corresponding increase in moisture content. Awad *et al.* (2005) demonstrated importance of fat and moisture as the filler with the network of cheese, whilst water acts as a lubricant or plasticizer between proteins. Softening the protein matrix is greatly affected by moisture in non fat cheese (Lucey *et al.*, 2003). However, the reduction of hardness with using inulin may be attributed also to modification of the protein structure of the cheese with inulin, which entrapped in the matrix serving to weak the elastic cheese matrix. According to Koca and Metin (2004), the softening effect observed in the cheese with inulin could be attributed to both the higher ratio of moisture to protein and to the increase in filler volume that results in a decrease in the amount of protein matrix.

In relation to the decreased hardness, the adhesiveness followed the same trend of results (Table 4). However, a gradual decrease was recorded with increasing inulin content in fresh cheese, whereas a significant increase was observed at the end of storage. Adhesiveness significantly decreased (P<0.05) by removing fat. Low fat UF- soft cheeses made with inulin had less adhesiveness than their in full-fat counter parts. The same was given by Bryannt *et al.,* (1995); Awad *et al.,* (2005) found that adhesiveness was significantly (P<0.05) higher in low fat UF- soft cheeses made with inulin. Adhesiveness implies a decrease in elasticity and an increase in water-protein matrix interaction. Since the inulin is responsible for the greater water retention in the cheese (probably through hydrogen binding), there is an increase of water-protein matrix interaction, and hence, adhesiveness. Both cheeses without inulin showed less adhesiveness during storage, but low fat UF- soft cheeses made with higher levels of inulin became more adhesive during storage. This increase may be due to the ability of proteins to interact with water (Pastorino *et al.,* 2003), which increases as a consequence of the hydrolysis of proteins during storage.

Springiness is the rate at which a deformed material returns to its original shape on removal of the deforming force (Szczesniak *et al.,* 1963; Bourne, 1978). In spite of cheese with IN7 had the lowest springiness among all cheeses, the differences in fresh cheese treatments (IN1, IN3 and IN5) samples were insignificant, and were insignificant also at the end of storage period.

Using inulin instead of fat in the treatment of milk retentate increased cohesiveness and decreased gumminess of fresh cheese. The presence of inulin in the cheese matrix (Table 4) may also be a mitigating factor in this respect. low fat UF- soft cheeses is known to possess more springiness (insignificant differences in the present study) because fewer fat globules are present and hence more casein is deformed per unit volume. However, springiness reflects the rubbery property of the produced cheese. It is unfavorable to be found as distinctive property in soft cheese. Whereas adhesiveness is the tendency of cheese material to adhere with other

material or surface and cohesiveness is the strength of internal bonds making up the body of the product (Szczesniak, *et al.,* 1963; Bourne, 1978).

Table (4): Rheological properties of fresh and stored synbiotic UF soft cheese made with probiotic ABT-2 culture and different level of inulin.

Treatments	Hardness (N)	Adhesiveness (J)	Springiness (mm)	Cohesiveness (ratio)	Gumminess (N)	Chewiness (J)
Fresh						
FFC	676.50 ±11.8^{E}	351.05 ±56.8^{B}	8.76 ±0.09^{B}	0.57 ±0.02^{B}	385.50 ±9.3^{C}	3374.25 ±83^{B}
LFC	792.00 ±6.1^{F}	239.51 ±15.9^{A}	8.36 ±0.18^{B}	0.62 ±0.01^{B}	493.38 ±1.7^{D}	4124.15 ±93^{C}
IN1	637.50 ±10.8^{D}	337.21 ±31.9^{B}	8.67 ±0.30^{B}	0.60 ±0.0^{AB}	380.75 ±12.1^{C}	3307.19 ±187^{B}
IN3	558.00 ±13.3^{C}	223.62 ±5.7^{A}	8.59 ±0.16^{B}	0.63 ±0.00^{B}	349.13 ±9.0^{BC}	3000.39 ±107^{B}
IN5	519.63 ±5.4^{B}	219.04 ±11.5^{A}	8.05 ±0.22^{AB}	0.62 ±0.00^{B}	322.75 ±3.2^{B}	2595.43 ±64^{B}
IN7	420.88 ±1.1^{A}	211.16 ±3.1^{A}	6.58 ±1.32^{A}	0.55 ±0.03^{A}	258.50 ±37.9^{A}	1781.73 ±538^{A}
Stored						
FFC	420.25 ±3.0^{D}	251.92 ±25.2^{AB}	9.23 ±0.24^{A}	0.54 ±0.03^{A}	254.50 ±39.5^{B}	2322.97 ±292^{B}
LFC	487.75 ±5.5^{E}	246.50 ±13.7^{AB}	9.22 ±0.26^{A}	0.53 ±0.02^{A}	254.50 ±7.4^{B}	2367.79 ±111^{B}
IN1	376.13 ±8.6^{C}	226.04 ±18.5^{A}	9.45 ±0.25^{AB}	0.54 ±0.05^{A}	205.25 ±25.3^{AB}	1935.52 ±227^{AB}
IN3	339.17 ±1.3^{AB}	352.28 ±3.9^{C}	8.94 ±0.03^{AB}	0.47 ±0.01^{A}	161.00 ±2.3^{A}	1489.73 ±18^{A}
IN5	345.25 ±1.6^{B}	287.61 ±12.3^{B}	9.99 ±0.14^{B}	0.48 ±0.02^{A}	165.13 ±8.1^{A}	1651.40 ±98^{A}
IN7	328.38 ±3.5^{A}	291.13 ±14.7^{B}	10.12 ±0.27^{B}	0.50 ±0.02^{A}	163.75 ±6.1^{A}	1660.00 ±98^{A}

Means ± SE with unlike superscripts are significantly different (*P*<0.05), whereas details of treatments were given in legend of table (1)

The lower values of chewiness in IN7 fresh cheese (Table 4) compared to the other treatments may be due to effect of inulin on changes the protein structure since inulin reduced hardness of cheese as recorded before. Inulin seems to share on decreasing chewiness of the cheese since the values given for fresh cheese decreased with increasing the amount of inulin added. Advancing storage period decreased chewiness of the tested cheese since the values decreased during storage of all cheese. Overall, rheological characteristics (hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness) were significantly lower in most cheeses samples made with inulin while these results were confirmed by Juan, *et al.,* (2013) who found that cheeses produced with inulin was less hard, springy, cohesive and chewy than reduced-fat cheeses, and more similar to cheeses made from whole milk.

The sensory evaluation given in Table (5) showed that fresh UF-soft cheese made without inulin (LFC) ranked the lowest scores for flavour, body & texture and appearance among all treatments. Using inulin at 7% (IN7) significantly improved all the pre-mentioned properties. Such impact may be due to effect of inulin on moisture, acidity and WSN/TN during cheese storage which greatly contributed in the attained improvement. The scores

given for the flavour, body & texture and appearance of control without inulin (FFC) were significantly higher than LFC and the other treatments, suggesting the important role of milk fat in such improvement from one side and the contribution role of inulin as a fat replacer from the other-side. This was also observed in cheese made using 5 and 7 % inulin which had significantly higher scores than those of the corresponding control cheese (without inulin). The total scores given for the resultant cheese were significantly higher than those given for the control. Such results are in agreement with those obtained by Stanton *et al.* (1998); Buriti *et al.* (2005; 2007) and Vajiheh *et al.,* (2012).

Table (5): Sensory evaluation of fresh synbiotic UF soft cheese made with probiotic ABT-2 culture and inulin.

Treatments	Flavour (50)	Body &Texture (40)	Appearance (10)	Total (100)
FFC	45.43 ±0.87^{D}	34.29 ±1.11^{AB}	8.14 ±0.40^{AB}	87.86 ±1.97^{D}
LFC	37.43 ±0.90^{A}	33.71 ±0.42^{A}	7.29 ±0.42^{A}	78.43 ±1.04^{A}
IN1	37.86 ±1.20^{AB}	34.29 ±0.42^{AB}	8.43 ±0.20^{B}	80.57 ±1.45^{AB}
IN3	39.57 ±0.84^{ABC}	35.71 ±0.42^{BC}	8.14 ±0.40^{AB}	83.43 ±0.97^{BC}
IN5	40.43 ±0.97^{BC}	36.43 ±0.30^{CD}	8.71 ±0.29^{B}	85.57 ±1.00^{CD}
IN7	42.43 ±0.90^{C}	37.71 ±0.18^{D}	8.86 ±0.26^{B}	89.00 ±1.02^{D}

Means ± SE with unlike superscripts are significantly different (*P*<0.05), whereas details of treatments were given in legend of table (1)

The most obvious effect of inulin addition was the overall improvement of the cheese mouth feel. It is most likely that the sensory improvement may be a result of inulin capability to form micro-crystals when dissolved in water or milk. Also, inulin had improved creaminess. The effect of creaminess increased with the rise of the inulin content in cheese (Guggisberg *et al.,* 2009).

It may be of interest to point out that the sensory evaluation was in the same line with most of the parameters of chemical composition, microbiological analysis and the rheological profile of the cheese. So, synbiotic UF-soft cheese of good quality could be made with inulin at levels of 5 or 7 % (w/w) from the original retentate weight. Also, the resultant cheese had less hardness with improving most of the other rheological properties.

In conclusion, the use of inulin in making low fat UF-soft cheese with probiotic ABT- 2 culture gave best optimum conditions for survival and activity of *Bifidobacterium BB-12* and *Lb. acidophilus* added to cheese. The resultant soft cheese can be used as a synbiotic delivery vehicle for better health of the consumer.

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استخدام الالياف الغذائية كالانيولين لانتاج الجبن الطرى الوظيفى

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يهدف البحث دراسة امكانية الاستفادة من الانيولين كمكون غذائى وظيفى لـة تـأثير مخفز للبكتريـا الداعمـة للحيويـة و كبـديل لـدهن اللبن فـى صـناعة الجبن الطـرى من مركـز اللبن النـاتج المـنخفض الـدهن مـن الترشيح الفوقى لذلك تم دراسـة تـأثير اضـافة الانيولين بنسبة ١ ، ٣، ٥، ٧ % فـى وجـود بـادئ ABT الداعم للحيويـة علـى التركيـب و بعض الخـواص الفيزوكيماويـة و الريولوجيـة و الحسية وكـذلك الاعداد المتاحـة مـن البكتريا الداعمة للحيوية و الريولوجية و كذلك الخواص الحسية خلال التخزين على ٥٧ م .

- أوضـحت النتـائج أن استخدام الانيولين بالنسب المختلفة أدى إلـى زيـادة محتـوى الرطوبـة و الرمـاد للجبن الطازج والمخزن تناقص المحتوى من البروتين أما بالنسبة للحموضة و النتروجين الذائب فزادت غالبا مع إضافة الانيولين. أما بالنسبة لحيوية بكتريا *Bifidobacterium BB12* *فكانت تزيد بإضـافة الانيولين* بنسب ٥% ، ٧% لاستخدامه كـ محفز لهـا مقارنـة بالمعاملـة بـدون إضـافة ولكن انخفضـت قليلا خـلال فتـرات التخـزين المختلفـة إلا أنهـا احتفظـت بالمسـتوى الحيـوي المـؤثر صـحياً(١٠ ٦). لكـن حيويـة *acidophilus Lb.* انخفضت مع تلك المستويات من الاينولين الا ان الاعداد فى المدى المؤثر حيويا.

- اتصـف الجبن النـاتج بصـلابة اقل و قيم أقل واختلافـات معنويـة فـى بـاقى صـفات التركيـب للجبن الطـازج والمخـزن مقارنـة بـالجبن الكنتـرول المـنخفض الـدهن بـدون اضـافة الانيولين. وحـازت الجبن النـاتج باضـافة ٥ ، ٧ % انيولين على أعلى درجات للتحكيم الحسي سواء للقوام والتركيب والمظهر العام وتقاربت مع الجبن الناتج من اللبن المركز كامل الدسم مقارنة بجبن المعاملات الأخرى.

توصى النتائج المتحصل عليها فى هذه الدراسة إمكانية استخدام بكتريا البروبيوتك خاصـة *Lb. acidophilus* و*Bifidobacterium BB12* مع ٥ ، ٧ % الانيولين محفز لنموتلك البكتريا الداعمـة للحيويـة لانتـاج الجبن الطرى المنخفض الدهن الوظيفى ويشترط فى ذلك حفظها تحت تبريد لمدة لاتزيد عن ٢٠ يوم حتى نضمن وجودها بأعداد مناسبة فى الجبن النـاتج (٨١٠-٩١٠ خلية/جم) بحيث تصل إلى الأمعاء فى حيويـة مع محفزها فتكون اكثر فاعلية لصحة العائل.

قام بتحكيم البحث

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