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Production of Low Fat Cheddar Cheese Made Using Exopolysaccharide-Producing Cultures and Selected Ripening Cultures

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Abstract

Low fat cheeses often suffer from undesirable texture and flavor. The objective of this study is to improve the yield, texture, flavor and quality of low fat Cheddar cheese during ripening using exopolysaccharide-producing lactobacilli and ripening cultures. The article represents one of the first attempts to tackle both texture and flavor at the same time. The study reveals the effect of aging on the texture and flavor of low fat Cheddar cheese over a ripening period of six months. The cheese manufactured with a modified protocol using EPS-producing cultures and ripening cultures showed higher values for moisture content (45%) and yield (9.4%) when compared to cheese manufactured with the conventional procedure and without the addition of EPS-producing cultures and ripening cultures (37.7%) and (4.9%) respectively. The obtained results indicated a 70% decrease in the fat content of the cheese. Texture profile analysis (TPA) indicated that the hardness, the cohesiveness, the springiness, the gumminess and the chewiness of the cheeses made using the EPS-producing cultures decreased with aging. The texture of the ripened low fat cheese made using EPS-producing cultures was described as chewy, springy, cohesive and smooth. The use of the ripening cultures resulted in the elimination of the bitter flavor defect which is a common problem in low fat Cheddar.

Keywords

Exopolydaccharide, Ripening Culture, Low Fat Cheddar

1. Introduction

Over consumption of dietary fat is associated with various chronic illnesses [1]. This association has created in-

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creased consumer awareness and an increase in the demand for low-fat foods, including cheese [2]. However, the consumption of low/reduced-fat cheese is still low [3]-[6]. In fact, low-fat cheeses have low intensity of typical flavor and, may develop a bitter off-flavor and hard, rubbery, dry and grainy texture [7]-[9].

Difficulties arise when attempts are made to produce low fat variants of cheeses that are popular and established in the market as full fat varieties. In producing low fat variants of standard fat cheeses such as Cheddar, processing parameters must be altered substantially in order to produce an acceptable texture and flavor.

Different strategies were described to overcome both texture and flavor defects, which include the retention of higher moisture in the curd, which can partially replace fat and improve texture through cutting into larger cubes, lowering the cooking temperature, draining and milling at a higher pH. Stabilizers and fat replacers were also used to improve texture. This practice was often followed by off flavor development.

Exopolysaccharides-producing lactic acid bacteria (EPS-producing cultures) have been used to improve product functionality in the dairy industry by binding free water. They have been suggested for low fat Cheddar cheesemaking for several reasons. They have the ability to bind water and to increase moisture; exopolysaccharides increase moisture retention by water binding or entrapment within their 3-dimensional network. In addition, EPS seem to act as nuclei for the formation of large pores in cheese; they also increase the viscosity of the aqueous phase in cheese and modify its flow characteristics. In addition, EPS interfere with protein-protein interactions physically or through their interaction with proteins. Several studies highlighted the positive effect of EPS-producing cultures on the physical and functional properties of reduced fat Cheddar cheese [10]-[13]. Bitterness is a common defect in reduced fat Cheddar cheeses and reported to develop after 2 to 3 months of ripening of cheese made with an EPS-producing culture [14]. Because the EPS-positive strain was not a typical Cheddar cheese starter culture, it did not have an adequate peptidolytic system to further hydrolyze the bitter peptides to amino acids. Most, if not all, typical Cheddar cheese starters do not produce EPS. Special cultures had been suggested to overcome the flavor defects, bitterness, and unclean flavors [15]. However, it still remains a challenge to reduce fat and maintain the texture and flavor of a comparable full fat cheese.

Adjunct cultures are nonstarter lactic acid bacteria consisting mainly of *Lactobacillus* sp., which are used in addition to a standard mesophilic starter to improve and to enhance the flavor of cheese. However, for the role of the adjunct in cheese ripening to be maximized, the intracellular enzymes must be released from the cells into the cheese matrix, which explains much of the attention given to cell autolysis during ripening. There has been considerable interest in using defined strains of nonstarter lactic acid bacteria as adjunct cultures to accelerate and improve flavor and texture development during cheese ripening [16].

The objective of this study is to introduce three different strategies in order to reach a low fat Cheddar exhibiting sensory characteristics similar to the full fat product and can be cited as follows: 1) Bring changes to the manufacturing process including size of cubes after cutting, cooking temperature, speed and rate of stirring, the use of higher pH during the cheddaring and milling processes; 2) Addition of EPS-producing cultures described as ropy and capsular; 3) Addition of ripening cultures exhibiting a complex peptidase system.

2. Materials and Methods

2.1. Bacterial Strains

A starter mixture composed of the following groups of microorganisms: 1) The acid producing culture R704 composed of (*Lactococcus lactis* subsp *lactis* and *Lactococcus lactis* subsp *cremoris*) obtained from Chr. Hansen (Hørsholm, Denmark); 2) The EPS-producing cultures composed of (*Lactobacillus delbrueckii* subsp *lactis* and *Lactobacillus paraplantarum* were used for the manufacture of low fat cheddar cheese; 3) The ripening cultures composed of two *Lactobacillus paracasei* subsp *paracasei*. The EPS-producing cultures and the ripening cultures were selected, genetically identified and phenotypically characterized in the laboratory of the biochemistry of dairy microorganisms, Alexandria University.

Strain Characteristics

The exopolysaccharides-producing lactobacilli cultures were classified as capsular, ropy and unattached. When a colony was touched with a wire inoculating loop strings of 11 and 9 mm were formed by both *Lactobacillus delbrueckii* subsp *lactis* and *Lactobacillus paraplantarum* respectively (unpublished data).

The ripening cultures selected for their complex peptide hydrolase system composed of an aminopeptidase N, three dipeptidasesan X-prolyldipeptidyl-peptidase as well as a carboxypeptidase and a specific endopeptidase. In

addition to a general caseinolytic activity hydrolyzing αS1 and β-casein, several esterases releasing C4, C6 and C8 fatty acids were also detected in these strains (unpublished data).

2.2. Cheesemaking

Cheese was made in the Cheese Research Laboratory, Department of Dairy Science and Technology, Alexandria University. Raw cow's milk obtained from the university dairy farm was standardized to 1% fat in milk in the case of low fat cheese and 3% fat for full fat cheese. The milk was then pasteurized at 74˚C for 15 sec and cooled to 30˚C using an Actini model Acti-Joule pasteurizer. The cheese cultures consisting of the commercial starter, the two EPS-producing lactobacilli and the two ripening cultures were added according to the following six treatments:

1) FFC = control full fat cheese made using the conventional procedure in the presence of the commercial starter culture.

2) LFC1 = low fat cheese made using the conventional procedure in the presence of the commercial starter culture.

3) LFC2 = low fat cheese made using the modified protocol in the presence of the commercial starter culture.

4) LFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the ripening cultures.

5) EPSLFC = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the EPS-producing lactobacilli.

6) EPSLFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture, the EPS-producing lactobacilli as well as the ripening cultures.

Computerized mini-cheesemaking vats (INRA, Poliny, France) were used for cheesemaking. After 45 - 60 min of the addition of the previous mixture of cultures to milk at 30˚C, the pH was dropped (0.1%). Calcium Chloride (0.02%) was then added. sufficient rennet (Chymax, Chr. Hansen, Hørsholm, Denmark) was added to coagulate the milk in 30 min. The coagulum was then cut gently for 2 to 6 rpm to hold more moisture; the cubes are then cooked in the whey for 60 min by increasing the temperature to 36˚C and the curds were held at 36˚C for 20 min. After whey drainage, the curd was cheddared for approximately 60 min at 36˚C and then milled at pH 5.6. The curd was salted to reach 1.5% in the finished cheese and pressed over night. Cheese is ripened at 8˚C, 85% relative humidity for 6 months. Samples from each treatment were analyzed in triplicate at zero, 1, 30, 60, 90, 120, 180 days. The full fat Cheddar cheese control was made according to the conventional procedure [17] and could be summarized as follows: full fat Cheddar cheese was made from 3% fat. Pasteurized milk was warmed to 30˚C and inoculated with the starter culture. Rennet was then added to coagulate the milk in 30 min. The coagulum was then cut and the temperature gradually raised to 39˚C (0.2˚C/min). Whey was drained and the curd cheddared for 110 min until the pH reached 5.3 ± 0.5, it was then milled, dry salted and pressed overnight. Cheese is ripened at 8˚C, 85% relative humidity.

2.3. Chemical Analysis

Cheeses were analyzed for moisture using the moisture analyzer (Mettler Toledo model HR73), salt content was determined using the chloride meter (Jenway, England, UK) and total protein by Kjeldahl method. The pH of cheeses was measured in slurry prepared by macerating 20 g of cheese in 20 ml of deionized water using a glass electrode (Jenway, 5303). The percent fat was also considered [18]. The cheese yield was calculated as the mass ratio between the curds obtained after the pressing stage and the weight of milk.

2.4. Texture Profile Analysis (TPA)

Textural properties of cheese were evaluated using a texture analyzer (TA1000, Lab Pro (FTC TMS-Pro), USA). Cheese samples were cut into 30 mm^3 cubes, samples were allowed to stand at ambient temperature for at least 1h before testing. A two-bite penetration test was performed and operated at a crosshead speed 50 mm/sec. Hardness, cohesiveness, springiness, gumminess and chewiness were evaluated in triplicate [19] [20].

2.5. Sensory Evaluation

Ten experienced panelists were provided with 20 mm^3 cubes of each cheese. The cheeses were tempered at 25˚C

for 1 h and were served at this temperature. Deionized water was given to panelists to clean their palates between each sample and reference cheese was provided into the tested samples. Samples were presented in identical containers labeled with a random number. The cheese samples were assessed for the following flavor attributes: unclean and bitter as well as the following cheese texture attributes: crumbly, firmness, smooth and springy. Scores of 1 considered low, while 5 and 9 indicated medium and high attribute respectively.

2.6. Statistical Analysis

All samples were carried out in duplicate and all analysis was done in triplicate. Statistical analyses were performed with Fisher's least-significant differences and LSD procedures available with the SAS software package, 2008 with a considered significant at $P < 0.05$. Significant differences between treatments were tested by ANOVA.

3. Results and Discussion

3.1. Chemical Composition

The obtained results concerning the composition of Cheddar cheese (**Table 1**) revealed that decreasing the fat content of cheese milk resulted in an increase in cheese moisture and protein and a decrease in cheese yield. These observations are in agreement with the data reported by several authors [10]-[12] [21]-[23].

Preliminarily data revealed that the best manufacturing conditions in the presence of selected EPS producing cultures and ripening cultures are larger curd size after cutting, lower scalding temperature at 36˚C, lower stirring speed, higher drainage, cheddaring pH at (5.6) and lower pressing force. Low fat cheese made using the modified protocol showed an increase of 1.2% in yield and 2.3% moisture when compared to the low fat cheese made using the conventional protocol. Previous contributions [24]-[26] revealed that lowering the cooking or scalding temperatures, reducing the stirring speed and milling at high pH can be used to increase the moisture content in low fat cheese. When EPS-producing cultures were added during the making of low fat cheese using the modified protocol, the resultant cheese exhibited higher moisture and yield than low fat made without the addition of the EPS-producing cultures.

Table 1 showed that the values of the moisture and the yield of the LFC1 were 40% ± 0.3 and 6.1% respectively. Addition of the EPS-producing cultures led to a significant increase of both moisture and yield which reached 45% ± 0.5 and 9.4% respectively. The yield value of the EPSLFC + Rp is close to that of the full fat cheese.

Our results revealed that the addition of our selected combination of EPS-producing cultures and ripening cultures and the modification of the manufacturing protocol affected the yield of low fat Cheddar cheese. The fat level of the EPS low fat Cheddar cheese is (10%) and (32%) in the case of the full fat cheese which indicated a 70% decrease in the fat content of the cheese. No significant differences in pH were found between EPS low fat cheeses and full fat after four months of ripening.

Table 1. Chemical analysis and cheese yield after manufacture[1].

Treatments[2]	pH	Moisture % wt/wt	Fat % wt/wt	Salt % wt/wt	Protein % wt/wt	Yield %
FFC	5.14^{a}	37.14^{c}	32.1^{a}	1.52^{a}	27.23^{d}	10.2^{a}
LFC1	5.27^{a}	37.71^{c}	10.15^{b}	1.56^{a}	39.15^{a}	4.9^{e}
LFC2	5.29^{a}	40.02^{b}	10.12^{b}	1.54^{a}	37.12^{b}	6.1^{d}
LFC + AJ	5.23^{a}	40.26^{b}	10.41^{b}	1.54^{a}	37.59^{b}	8.7^{c}
EPSLFC	5.27^{a}	45.28^{a}	9.8^{c}	1.53^{a}	34.22^{c}	9.2^{b}
EPSLFC + AJ	5.20^{a}	45.73^{a}	9.8^{c}	1.53^{a}	34.57^{c}	9.4^{b}

$^{a-e}$Mean ± standard deviation followed by the same letter's are not significant, but different letters are significant according to LSD procedure ($P < 0.05$). [1]Samples were taken after pressing; [2]FFC = control full fat cheese made using the conventional procedure in the presence of the commercial starter culture; LFC1 = low fat cheese made using the conventional procedure in the presence of the commercial starter culture; LFC2 = low fat cheese made using the modified protocol in the presence of the commercial starter culture; LFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the ripening cultures; EPSLFC = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the EPS-producing lactobacilli; EPSLFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture, the EPS-producing lactobacilli as well as the ripening cultures.

3.2. Texture Analysis

In order to study the impact of the EPS producing cultures, ripening cultures and the changes in the manufacturing conditions on the textural characteristics of low fat Cheddar cheese, the following parameters were considered.

3.2.1. Hardness

The results describing the hardness of full fat and low fat cheeses revealed significantly higher values in low fat cheese manufactured using the conventional procedure which led to an extremely hard cheese (**Figure 1(a)**). These observations are comparable to previous findings [21] [27]. Modifications of the cheesemaking protocol led to a slight decrease in hardness that can be attributed to the increase in the moisture level of the cheese. On the other hand, addition of the EPS-producing cultures (*Lactobacillus delbrueckii* subsp *lactis* and *Lactobacillus paraplantarum*) was the major contributor to hardness decrease. In fact a 70% decrease in hardness was observed in EPSLFC and EPSLFC + Rp after cheesemaking when compared to LFC2 (**Figure 1(a)**). These observations are comparable to previous studies that highlighted the positive effect of EPS-producing cultures on the physical and functional properties of reduced fat Cheddar cheeses [10]-[13]. During the first three months of ripening, a decrease in hardness was observed in all cheeses followed by an increase of all treatments after four months of ripening; this may be due to the breakdown of the casein and the increase of protein-protein interactions. Creamer and Olson [28] attributed the increase in the hardness values during ripening to the increase of the concentration of free amino acids and small peptides formed by casein hydrolysis, which be able to bind free water molecules and consequently increase the strength of the casein matrix and thus increase the resistance of cheese to deformation. A similarity was observed between the hardness of FFC, EPSLFC and EPSLFC + Rp during ripening; this is probably due to the proteolytic activity of the added adjunct cultures during ripening. After six months of ripening, EPSLFC + AJ showed firm but cohesive texture when compared to FFC which exhibited crumbly texture; these results indicate the effective impact of the EPS-producing cultures to modify the hardness of low fat Cheddar cheese. Similar observations were previously reported [11] [12] which showed that EPS may have an important role in modifying reduced fat Cheddar cheese textural properties. Madkor,

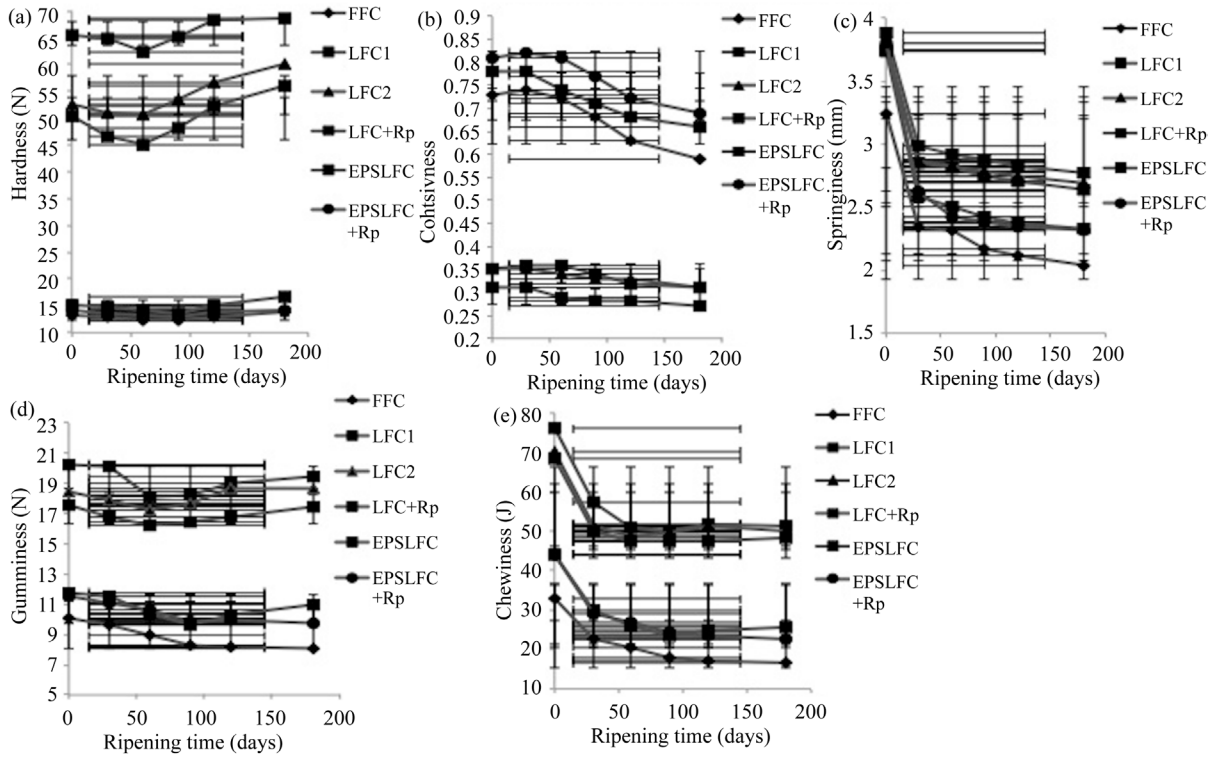

Figure 1. Evaluation of texture parameters over ripening.

Tong, and El Soda [29] reported that the higher proteolysis rates of some adjunct treated cheeses may be associated with the decrease in firmness particularly in low fat cheese. Enhanced breakdown of the casein matrix especially α-casein has been associated with improved texture and smooth body in reduced fat cheese.

3.2.2. Cohesiveness

The evaluation of cohesiveness in the different treatment is shown in (**Figure 1(b)**). LFC2 exhibited better cohesiveness when compared to LFC1. Addition of the EPS-producing cultures had a positive impact on the cohesiveness of low fat cheeses. EPSLFC and EPSLFC + Rp cheeses exhibited significantly higher values of cohesiveness when compared to LFC1 and LFC2. During ripening, a decrease in cohesiveness in all treatment was observed; this is due to the decrease in moisture content and the proteolysis during ripening. Cheese cohesiveness was shown to decrease as cheese moisture content decreases [30]. Cheese cohesiveness is inversely related to cheese proteolysis, with a trend of decreasing with increasing proteolysis [31]. The EPSLFC and EPSLFC + Rp showed more cohesive than FFC after 4 and 6 months of ripening, this is be probably due to the proteolysis caused by the addition of the two *Lactobacillus paracasei* subsp *paracase*i strains. Proteolysis disrupts the structural integrity of the protein matrix, leading to reduced cohesiveness [11].

3.2.3. Springiness

Results of springiness for the full fat and different low fat cheese treatments are illustrated in (**Figure 1(c)**). Low fat cheese made using the conventional protocol exhibited higher values of springiness when compared to the full fat which is in agreement with Beal and Mittal [27], who found that as fat in Cheddar decreased, hardness, springiness and cohesiveness increased. The use of the modified protocol and the EPS-producing cultures in the making of the low fat cheese decreased the values of springiness. After the first month, a sharp decrease in springiness was measured in all treatments followed by a decrease in all treatments during the ripening period. This decrease in springiness values could be referred to the hydrolysis of the para κ-caseinate molecules, which are responsible for the springiness of cheese curd [32]. EPS low fat treated cheese showed springier than FFC. Costa *et al*. [23] reported that reduced fat Cheddar cheese exhibits more springiness that the full fat product.

3.2.4. Gumminess

The gumminess of the different treatment is illustrated in (**Figure 1(d)**). The obtained data reveals significant differences between the cheeses made with EPS-producing cultures (EPSLFC and EPSLFC + Rp) and the non EPS treated cheese (LFC1, LFC2 and LFC + Rp). EPS treated cheeses had lower gumminess values very close to FFC. These results were in agreement with previous studies [11].

3.2.5. Chewiness

Chewiness could be defined as the energy required chewing a solid food product to a state where it is ready for swallowing [19] [20]. As a general rule, FFC and EPS treated cheeses (EPSLFC and EPSLFC + Rp) showed the lower chewiness values than other treatments (**Figure 1(e)**). The highest chewiness values were observed in the case of LFC1 and LFC2. A sharp decrease for all treatments was observed after the first month of ripening, this phenomenon could not be detected for FFC. Similar observations were reported [11]. During ripening a decrease in chewiness was observed in all cheeses. There is a correlation between cheese hardness and chewiness, harder cheese is more difficult to chew [26].

3.3. The Sensory Evaluation

The sensory evaluation results indicated the presence of defects in both texture and flavor in the case of Cheddar cheese manufactured using the conventional protocol (**Table 2**). The texture can be described as rubbery and extremely firm. A pronounced bitter flavor defect as well as an unclean flavor was detected during ripening. Many reports have also shown that when the fat content of cheese is progressively reduced, the cheese develops an undesirable firm, weak, rubbery texture and flavor notes that are atypical for the corresponding full fat product [4] [21]. Numerous strategies have been applied to improve the texture of low fat cheese, which has been reviewed in several occasions [10] [11] [29]. However, it still remains a challenge to reduce fat and maintain the texture of a comparable full fat cheese. In ripened cheeses such as low fat Cheddar, an imbalance in flavor dur-

Table 2. Sensory evaluation of Cheddar cheeses during ripening.

Treatment[1]	Ripening period (months)	Sensory parameters					
		Flavor parameters		Texture parameters			
		Unclean	Bitter	Crumbly	Firmness	Smooth	Springy
FFC	2	$0.1^{c,e}$	$0.5^{b,c}$	$2^{a,b}$	$1.5^{a,c}$	$7^{b,b}$	$3^{b,c}$
	4	$0.6^{b,d}$	$0.5^{b,c}$	$2^{b,b}$	$0.7^{b,d}$	$9^{a,a}$	$5^{a,b}$
	6	$0.7^{a,d}$	$0.7^{a,c}$	$3^{b,b}$	$0.7^{b,d}$	$9^{a,a}$	$5^{a,b}$
LFC1	2	$2.8^{c,d}$	$2^{c,b}$	$8^{a,a}$	$6^{b,b}$	$1^{a,d}$	$0^{a,d}$
	4	$5.6^{b,b}$	$6^{a,a}$	$9^{a,a}$	$9^{a,a}$	$0^{a,d}$	$0^{a,d}$
	6	$6.4^{a,a}$	$8^{a,a}$	$9.5^{a,a}$	$9.3^{a,a}$	$0^{b,d}$	$0^{a,d}$
LFC2	2	$2.7^{c,d}$	$2^{b,b}$	$7^{a,a}$	$6^{b,b}$	$1^{a,d}$	$0^{a,d}$
	4	$3.9^{b,b}$	$6^{a,a}$	$7^{a,a}$	$8^{a,a}$	$1^{a,d}$	$0^{a,d}$
	6	$4.7^{a,a}$	$7^{a,a}$	$7^{a,a}$	$8^{a,a}$	$0^{b,d}$	$0^{a,d}$
LFC + AJ	2	$0.4^{c,e}$	$1^{a,c}$	$6^{a,a}$	$7^{b,b}$	$1^{b,d}$	$0^{b,d}$
	4	$1.2^{b,c}$	$1^{a,c}$	$6^{a,a}$	$8^{a,a}$	$2^{a,c}$	$0^{b,d}$
	6	$1.8^{a,b}$	$0.7^{a,c}$	$6^{a,a}$	$8^{a,a}$	$2^{a,c}$	$1^{a,d}$
EPSLFC	2	$0.3^{c,e}$	$3^{b,d}$	$2^{a,c}$	$2^{a,c}$	$6^{b,b}$	$4^{b,b}$
	4	$0.7^{b,d}$	$5^{a,b}$	$1^{a,b}$	$1^{b,d}$	$7^{a,a}$	$6^{a,a}$
	6	$0.7^{a,c}$	$5^{a,b}$	$1^{a,b}$	$1^{b,c}$	$7^{a,a}$	$6^{a,a}$
EPSLFC + AJ	2	$0.2^{c,e}$	$0.8^{b,c}$	$1^{a,c}$	$1^{a,c}$	$7^{b,b}$	$4^{b,b}$
	4	$0.8^{b,d}$	$0.5^{a,c}$	$0.3^{b,d}$	$0.5^{b,d}$	$8^{a,a}$	$7^{a,a}$
	6	$0.9^{a,d}$	$0.5^{a,c}$	$0.3^{b,d}$	$0.5^{b,d}$	$8^{a,a}$	$7^{a,a}$

[a-d]Mean ± standard deviation followed by the same letter's are not significant, but different letters are significant according to LSD procedure ($P < 0.05$). [1]FFC = control full fat cheese made using the conventional procedure in the presence of the commercial starter culture; LFC1 = low fat cheese made using the conventional procedure in the presence of the commercial starter culture; LFC2 = low fat cheese made using the modified protocol in the presence of the commercial starter culture; LFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the ripening cultures; EPSLFC = low fat cheese made using the modified protocol in the presence of the commercial starter culture and the EPS-producing lactobacilli; EPSLFC + Rp = low fat cheese made using the modified protocol in the presence of the commercial starter culture, the EPS-producing lactobacilli as well as the ripening cultures.

ing ripening is also observed along with the development of bitterness [9]. A slight improvement in texture characteristics was observed in the low fat cheese LFC2 manufactured using the modified protocol. The sensory evaluation of the EPS-treated cheeses revealed a significant improvement in texture characteristics, which is clearly shown in **Figure 2**. In fact, no significant differences in firmness were observed between FFC and cheeses made using EPS-producing cultures during the ripening period. On the other hand, FFC was found to be smoother, more crumbly and less springy than cheeses made using EPS-producing cultures after four and six months of ripening. The flavor evaluation of the different cheese samples revealed the following: LFC1 and LFC2 as well as EPSLFC samples showed an extremely pronounced bitter flavor which was detected after starting the second month of ripening. The highest levels of bitterness were detected after the fourth month of ripening. It was clearly demonstrated during this stage *Lactobacillus paracasei* subsp *paracasei* played a very effective role in reducing bitterness and improving the flavor of low fat cheese. The sensory evaluation of the different Cheddar cheeses in **Table 2** revealed that EPSLFC was significantly much bitter than EPSLFC + Rp and FFC, this trend could observed during the whole ripening period. On the other hand, no significant differences in bitterness could be measured between FFC, LFC + Rp and EPSLFC + Rp can be to the debiterrase system of the ripening cultures. Adjunct treated cheeses rapidly developed the highest flavor score after three months of ripening when compared to LFC1 and LFC2. The panelist comments indicated that LFC1 and LFC2 lacked flavor after three months of ripening and with extended ripening tented to develop bitterness. Flavor scores in cheeses made with adjunct cultures were highest at 3, 4 and 6 months of ripening and tended to have higher texture scores, relatively softer body and less firmness compared to control cheeses. Many reviews studied the use of ripening cultures for the enhancement of flavor and texture in low fat Cheddar cheese [16] [29].

Adjunct cultures not only have a role in flavor development in ripened cheeses but may also be used to enhance functionality of low fat cheeses. Madkor, Tong, and El Soda [29] reported that adjunct culture positively influenced flavor and texture attributes in reduced fat Cheddar by preventing bitterness and reducing firmness. El Soda, Madkor, and Tong [16] demonstrated that the addition of adjunct cultures had a positive impact on low fat cheese quality and are an important contributor to the development of characteristic Cheddar cheese flavor.

In order to evaluate the Cheddar flavor quality in cheese samples we compared between the flavor of FFC Cheddar and the EPSLFC + Rp to the flavor of Cheddar cheese samples imported from Ireland and USA. The obtained data (**Table 3**) revealed that among all the samples evaluated the full fat cheese imported from the USA obtained the highest scores for both texture and flavor, followed by the EPSLFC + Rp. The lowest scores for both texture and flavor were obtained in the case of low fat Cheddar imported from Ireland.

4. Conclusion

This study has tackled the two major problems facing low fat cheese, texture and flavor. Texture defects were overcome using two strategies; a modified make procedure and the addition of two *Lactobacillus* strains producing exopolysaccarides. Bitterness formation was eliminated using two *Lactobacillus paracasei* subsp *paracasei* strains known for their debit erase activity. It is also believed that it is the joint action of the different microorganisms added to the cheese milk that contributed to the formation of the characteristic Cheddar cheese flavor that was comparable and is some cases preferred to the flavor of full fat cheese imported from England, Ireland and the USA. This study reveals for the first time the availability of a culture mixture capable of producing a Cheddar cheese containing 10% fat with sensory characteristics comparable to a full fat Cheddar.

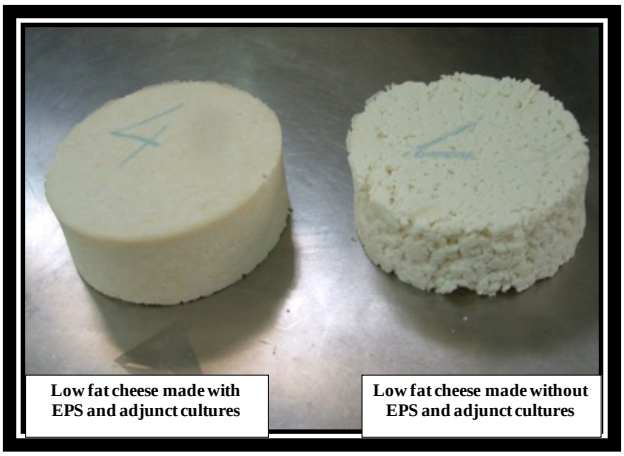

Figure 2. Low fat Cheddar cheese made with and without EPS producing cultures.

Table 3. Sensory evaluation of Cheddar cheeses[1].

Treatments[2]	Flavor evaluation	Texture evaluation	Cheddar notes
FFC	8.9[b]	8.6[b]	8.5[b]
EPSLFC + AJ	8.7[b]	9.4[a]	8.7[b]
KRAFT sharp	9.2[a]	8.9[b]	9.5[a]
KRAFT mild	7.4[c]	7.2[c]	7.7[c]
Kerrygold reduced fat	4.6[d]	3.5[d]	4.3[d]
CABOT Vermont	8.8[b]	7.9[c]	8.1[c]

[a-d]Mean ± standard deviation followed by the same letter's are not significant, but different letters are significant according to LSD procedure ($P < 0.05$). [1]Samples were taken after four months of ripening; [2]FFC = control full fat cheese made using the commercial starter culture and made with the conventional procedure; EPSLFC + AJ = low fat cheese made using the commercial starter culture in addition to the two strains of the EPS-producing cultures and the two strains of the adjunct cultures and made with the modified protocol; KRAFT sharp = KRAFT Cracker barrel (sharp) imported from USA; KARFAT mild = KRAFT mild Cheddar cheese imported from USA; Kerrygold reduced fat = 50% reduced fat sharp Cheddar cheese imported from Ireland; CABOT Vermont = 50% reduced fat sharp Cheddar cheese imported from USA.

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