Food Structure

Volume 8 | Number 1 Article 15

1989

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FOOD MICROSTRUCTURE, Vol. 8 (1989), pp. 125-135
Scanning Microscopy International, Chicago (AMF O'Hare), IL 60666 USA

0730-5419/89$3.00+.00

RHEOLOGY AND MICROSTRUCTURE OF STRAINED YOGHURT (LABNEH) MADE FROM COW'S MILK BY THREE DIFFERENT METHODS

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Abstract

Labneh is the name for strained yoghurt, i.e., yoghurt made with an elevated solids content, which has originated in the Middle East. For this study, three types of Labneh were made from cow's milk: (a) "Traditional Labneh" was produced by straining yoghurt in a cloth bag, (b) "UF Labneh" was made by ultrafiltration of warm yoghurt, and, (c) "UF Retentate Labneh" was obtained by culturing homogenised ultrafiltration (UF) milk retentate. All products were passed through a lactic curd homogeniser to smoothen the Labneh curd. Total solids contents of the products were within the range of 21.0 to 24.2%, protein was 6.8 to 8.2%, and fat was 9.2 to 10.5%.

Rheological properties such as consistency of traditional Labneh and UF Labneh were similar and no syneresis was observed after breaking the coagulum. The coagulum of the UF Retentate Labneh was very firm and its texture was crumbly. Syneresis was noticeable after the coagulum had been broken. The best sensory attributes were found with the UF Labneh followed by the traditional Labneh whereas the UF Retentate Labneh appeared not to be satisfactory.

Electron microscopy revealed that the microstructures of all three Labnehs were similar and consisted of casein micelle chains and clusters. Minute fat particles which originated from the homogenisation of milk or retentate were embedded in the casein micelle clusters. Smoothening somewhat reduced the dimensions of the casein particle chains and clusters in all Labnehs.

Initial paper received February 10, 1989
Manuscript received June 5, 1989
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KEY WORDS: Casein micelles, Labneh, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Streptococcus thermophilus*, Milk retentate, Scanning electron microscopy, Transmission electron microscopy, Strained yoghurt, Ultrafiltration of milk, Ultrafiltraion of Yoghurt.

Introduction

The origin of yoghurt-making in the Middle East dates back several thousand years. The nomads tending their herds prepared yoghurt in earthenware vessels or in containers made from animal skins. The product was kept in these containers until it was all consumed. It is probable that during this time, the liquid phase (whey) seeped through the container or evaporated. The strained yoghurt thus obtained, which has been called Labneh, would keep for a longer time than the original yoghurt, partly due to an increased lactic acid concentration which preserved it.

At present, modern manufacture of yoghurt is carried out under controlled conditions using low-fat or whole milk which is inoculated with mixed starter cultures of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Rasic and Kurmann, 1978; Tamime and Robinson, 1985, 1988a, 1988b; Marshall, 1987). In the Middle East, however, Labneh is still produced in the traditional manner with the cloth bag used universally for the straining of the yoghurt in spite of the centralized processing of milk in dairy plants.

Similar cultured milk products have been popular in various countries. Such products are known as Tan or Than in Armenia, Torba, Kurut, or Tulum in Turkey, Leben Zeer in Egypt, and Labneh or Lebneh in most Arab countries (Tamime and Robinson, 1978; El-Gendy, 1983; Abou-Donia, 1984). Other products closely related to Labneh are known as Chakka and Shirkhand in India, Skyr in Iceland, and Ymer in Denmark (Tamime and Robinson, 1988a).

The compositional standard of Labneh in Lebanon contains 26% total solids, 10% fat, and 1% salt, where as in Saudi Arabia, Labneh contains 22% total solids and 7% fat (Tamime and Robinson, 1988a). As a dish, Labneh is garnished with dried herbs and olive oil and is eaten with pita bread.

The traditional manufacture of Labneh is labour-intensive and unhygienic. Losses of the product due to its adherence to the cloth bags are quite high. Over the past ten years, attempts have been made to mechanize the process for creamery-scale operations. Several systems of manufacturing have been developed. In one of them, Labneh is produced from heated yoghurt by centrifugation (Dagher and Ali-Ghariebeh, 1985).

Sensory attributes of the product are similar to the traditional Labneh, i.e., Labneh obtained by draining yoghurt in a cloth bag. Alternatively, Labneh may be made by concentrating a mixture of yoghurt and brine (Kharrazi, 1984) using a centrifugal separator. In another method, warm skim-milk yoghurt is concentrated to the desired level of solids using a nozzle or quarg separator and cream is later blended with the product (Salji et al., 1983; Robinson and Tamime, 1986, Rasic, 1987). Labneh may also be made from ultrafiltration (UF) milk retentate by culturing using a mixed strain yoghurt starter culture (Veinoglou et al., 1978; Abd El-Salam and El-Alamy, 1982; El-Samragy and Zall, 1988; Hofi, 1988). In this study, the product thus obtained is referred to as "UF Retentate Labneh". Finally, warm yoghurt may be concentrated by ultrafiltration. This process is new in the production of Labneh and the product is referred to as "UF Labneh" (Tamime et al., 1989) in this study.

Labneh is a smooth cultured milk product, the body of which may further be smoothened by passing it through a lactic curd homogeniser.

The objective of this study was to examine the individual Labnehs by electron microscopy and to assess their microstructures with respect to the manufacturing procedures and rheological properties of the products.

Materials and Methods

Preparation of the milk

Whole cow's milk was obtained from the West of Scotland College Farm in January and March, 1988. In each trial the milk was divided into two portions for the production of Labneh using three different methods.

Production of Labneh

Three different types of Labneh were manufactured as described by Tamime et al. (1989), and in brief they could be described as follows:

Process I (UF Retentate Labneh) - The milk was pre-warmed to 50°C before concentration by UF to 22% total solids (TS) using an Alfa-Laval pilot scale plant (Fig. 1). The retentate was homogenised at 17.2 MPa, heated to 90°C for 5 min in a water bath (steam was used as heating medium), cooled to 42°C and inoculated with a yoghurt starter culture. The retentate was incubated (in bulk and in 150 mL plastic cups) until the acidity reached pH 4.6. After fermentation, the product was refrigerated overnight, the bulk portion of it was passed through the lactic curd homogeniser, dispensed into 150 ml plastic cups, and refrigerated at 5-7°C overnight.

Process II (UF Labneh) - Yoghurt was prepared according to the method described by Tamime et al. (1984), but without fortification of the milk solids. At the end of the incubation period, the warm yoghurt was concentrated by UF using the same Alfa-Laval plant (Fig. 1) and refrigerated in bulk and in 150 mL plastic cups overnight. The following day the bulk Labneh was passed through the lactic curd homogeniser, dispensed into 150 ml plastic cups and refrigerated at 5-7°C.

Process III (Traditional Labneh) - The yoghurt (in bulk) was produced as described in Process II above. The refrigerated yoghurt was mixed, emptied into a polyester cloth bag (Ets. Henri Bastien, 59157 Beauvois-en-Cambresis, France) and pressed overnight in a refrigerated room (Fig. 2). For every 10-12 kg of yoghurt, 4.5 kg weight was used to press the product during the drainage period. It was observed that some Labneh was lost, i.e. adhered to the bag, when collecting it. The Labneh was then processed and packaged as described above.

Ultrafiltration Plant

The milk and yoghurt were concentrated by using the same Alfa-Laval UF pilot scale plant reported by Tamime et al. (1984), but it was slightly modified. The specifications of the membrane were: type PM_2- 50 series No. 6 PL 1256 S, surface area 1.3 m^2, fibre internal diameter 1.5 mm, membrane material polysulfone and molecular weight cut-off 50,000 dalton.

Starter Culture

A commercial mixed strain of concentrated freeze-dried yoghurt starter culture MYO - 87 (Eurozyme Ltd., London, UK) was used to ferment the milk. This starter (i.e., direct to vat inoculation) was used at a rate of 16 units/100 L, and was incubated at 42°C.

Lactic Curd Homogeniser

The homogeniser type ALM (Pierre Guerin S.A., Mauze, France) was used to smoothen the Labneh at 7°C using a pressure of 8 MPa, and the homogeniser head employed was No. D-170 (Tamime and Crawford, 1984).

Rheological Analysis

A Stevens LFRA Texture Analyser (C. Stevens & Son Ltd., Hertfordshire, UK) was used to assess the consistency of Labneh. The operating conditions were:- cone type TA3-TFE 105-504 (25 x 35 mm cylinder), penetration distance 15 mm, speed of probe 0.5 mm/S and chart recorder (C. Stevens & Son Ltd.) operating at 200 mV and 30 mm/min chart speed.

The packaged Labneh in the plastic container was squeezed gently between the thumb and forefinger to visually assess the texture and elasticity characteristics of the product.

Microscopic Analysis

Labneh was sampled using a glass tube, 7.0 mm in diameter. Sample columns, approximately 10 mm long, were fixed in a 2.8% aqueous glutaraldehyde solution and mailed to Ottawa for electron microscopy (Allan-Wojtas, 1984). After arrival, the samples were prepared for scanning electron microscopy and for transmission electron microscopy similar to other milk gels (Kalab et al., 1983).

Scanning electron microscopy (SEM). The Labneh columns were cut into prisms, 1 x 1 x 10 mm, and the prisms were dehydrated in a graded ethanol series (20, 40, 60, 80, 96, and 100% ethanol). Dehydrated samples were defatted in chloroform, returned into absolute ethanol, rapidly frozen in Freon 12 at -150°C, and freeze-

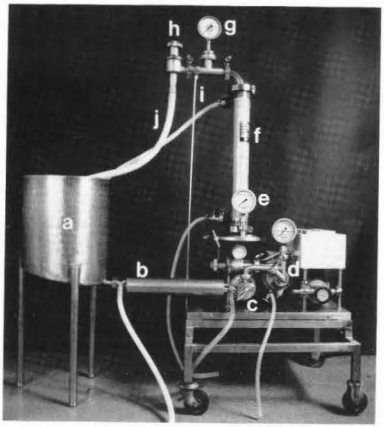

Fig. 1. Alfa-Laval pilot scale ultrafiltration equipment for the production of Labneh.
a: Balance tank; b: concentric tube for water circulation; c: feed pump number one; d: feed pump number two; e: inlet pressure gauge; f: Romicon hollow fibre membrane; g: outlet pressure guage; h: SMO-R valve; i: permeate outlet; j: recirculation and product outlet.
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Fig. 2. An illustration of stainless steel perforated baskets and trays for the production of traditional Labneh.

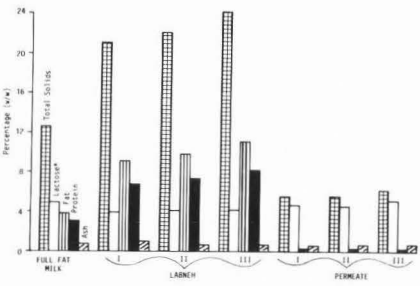


Fig. 3. Chemical composition (%) of milk, different types of Labneh and permeate.
I: UF Retentate Labneh; II: UF Labneh; III: traditional Labneh.
**Lactose was determined by difference.*
Results are average of two trials.

fractured under liquid nitrogen. The fragments were melted in absolute ethanol, critical-point dried, mounted on SEM stubs, sputter-coated with gold, and examined in an ISI DS-130 scanning electron microscope equipped with an external oscilloscope (Bond and Kalab, 1988).

Transmission electron microscopy (TEM). The Labneh samples were cut into approximately 0.5 x 0.5 x 0.5 mm cubes, washed with a 0.05 M veronal-acetate buffer, pH 6.8, postfixed for 2 h in a 2% osmium tetroxide solution in the same veronal-acetate buffer, dehydrated in ethanol, embedded in medium hard Spurr's low-viscosity resin (J.B. EM Service, Inc., Pointe Claire-Dorval, Quebec, Canada), and sectioned. Sections, approximately 90 nm thick, were stained with uranyl acetate and lead citrate solutions (Reynolds, 1963) and examined in a Philips EM-300 electron microscope operated at 60 kV. Micrographs were taken on 35-mm film.

Results and Discussion

The Labnehs under study were made in January and March, 1988 from two batches of whole cow's milk. The milk contained 12.5% total solids, 4.8% lactose, 3.9% fat, 3.1% total protein, and 0.7% minerals (Fig. 3). The composition of the Labnehs is summarised in Fig. 3. It is evident that the total solids, fat, and protein contents were proportionally increased in the products compared to the milk, whereas the lactose content was reduced in all Labnehs to a level that ranged between 4.0 - 4.4%. The highest total solids, fat, and protein contents were found in the traditional Labneh (24.2, 10.5, and 8.2%, respectively) and the lowest values were found in

the UF Retentate Labneh (21.0, 9.2, and 6.8%, respectively). These differences may be attributed to the extent of draining and the resulting increased concentration of the solids contents. Protein losses in the permeates and in the cloth bag filtrate were approximately the same, i.e., within the range of 0.2 to 0.3%. No fat losses were observed in any of the manufacturing processes used and, thus, the solids contents in the permeates and the filtrate consisted almost exclusively of lactose and minerals (Fig. 3).

Rheological properties of the Labnehs produced were to a great extent affected by the manufacturing procedure and, in particular, by the application of the lactic curd homogeniser to smoothen the products (Fig. 4). Similar results were obtained with Labnehs made in January as well as in March.

Unsmoothened UF Retentate Labneh was firmest (766 g) despite its lowest total solids and protein contents. Following the passage through the lactic curd homogeniser (shaded peak), the firmness of this Labneh dropped markedly to below 50 g. In the UF Labneh, the change in consistency (from 183 to 105 g) is due to the homogenisation which was not as extensive. Interestingly, traditional Labneh had the highest firmness (134 g) of all three homogenised Labnehs. It may be hypothesized that the differences in consistency are related to the way in which the coagulum was formed during the culturing of milk. Thus, the UF Retentate Labneh would resemble a set-style yoghurt whereas the other two Labnehs would be similar to the stirred-type yoghurt. It is a well-established fact that the passage of yoghurt through any restriction in the pipes causes structural damage to the coagulum (Galesloot, 1955; Steenbergen, 1971) and reduces its viscosity and/or consistency (Tamime and Robinson, 1985). Passage of Labneh through the lactic curd homogeniser undoubtedly also brings about similar changes.

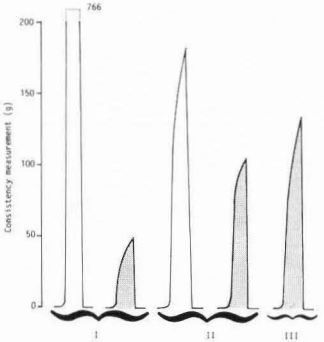


Fig. 4. The consistency (g) of different types of refrigerated Labneh using the Stevens-LFRA texture analyser.*
**Results are average of three readings at 7°C of the January trials.*

Product unsmoothened;

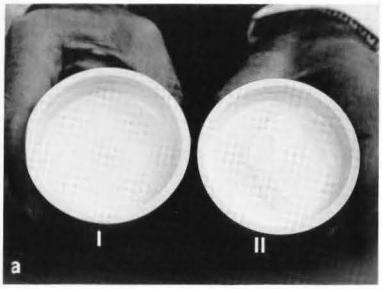
product smoothened (see text).
Labneh samples I, II & III are the same as in fig. 3).

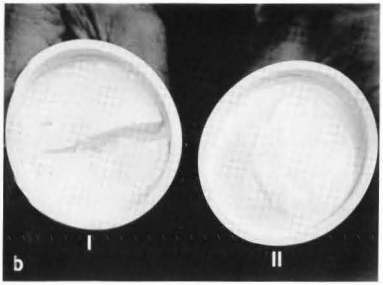
The absence of data on the consistency of unsmoothened traditional Labneh in Fig. 4 was caused by the heterogeneous nature of the product which resulted from draining the Labneh in a cloth bag. The layer of curd adhering to the cloth had a considerably higher total solids content than the central portion of the product and was lumpy. Consequently, a wide range of consistency readings was obtained when sampled for analysis. However, reproducible readings of 134 g were obtained after the Labneh had been smoothened by passage through the lactic curd homogeniser. Provided that the difference in the protein content between the traditional Labneh and the UF Labneh was taken into consideration, the consistency readings of both Labnehs were comparable (see Fig. 3 - black column).

Elasticity of Labnehs made by the various procedures and whey separation was monitored with the products stored in plastic containers. The UF Labneh and traditional Labneh behaved in a similar way both before and after smoothening. UF Retentate Labneh had a tendency to crack and crumble and was considerably less elastic than the UF Labneh. After the coagulum of the UF Retentate Labneh had been broken with a spoon, syneresis was immediately noticeable in contrast to UF Labneh which was free from this defect (Fig. 5).

It may be concluded on the basis of consistency measurements that UF Labneh and traditional Labneh are similar to each other whereas the UF Retentate Labneh is somewhat different (Fig. 4).

Concerning the microstructure as examined by electron microscopy, however, all Labneh samples were, in general, similar to each other irrespective of whether they had been or had not been smoothened. SEM at a low magnification showed, for example, that there were no noticeable differences in the microstructures of the UF Retentate Labneh before and after passage through the lactic curd homogeniser (Figs. 6 a and 6 b, respectively). The unsmoothened UF Labneh had a similar structure consisting of a relatively uniform matrix in which, occasionally, small lumps of fluffy protein aggregates were found to be hollow (Fig. 7a). Such lumps were not found after the Labneh had been passed through the lactic curd homogeniser (Fig. 7b). In the traditional Labneh, the difference between the unsmoothened and smoothened structure has also been subtle. The smoothened product, however, was found to be separated into fluffy areas, each less than 0.2 mm in diameter (Fig. 8). The apparent fluffiness of these areas did not interfere with the smooth perception of the product. It is probable that these areas were formed following the passage of the Labneh through the lactic curd homogeniser or during its slow cooling afterwards.





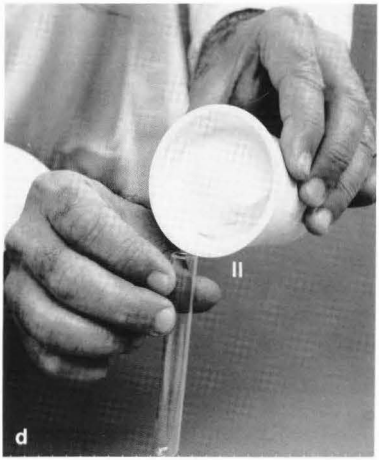
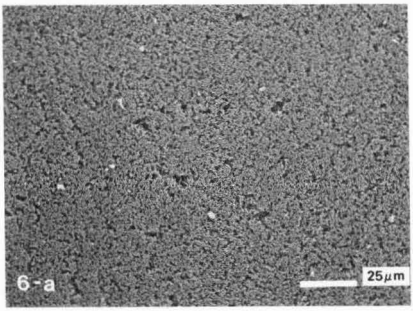
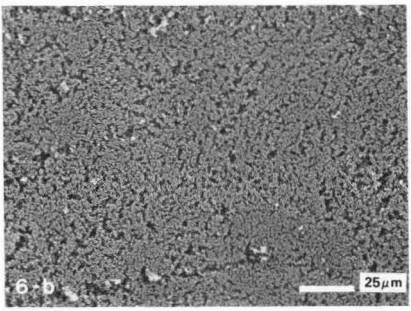


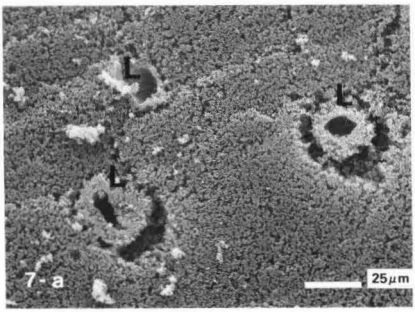
Fig. 5. The elasticity and whey separation of UF Retentate Labneh (I) and UF Labneh (II). a: General appearance of Labneh; b: the elasticity of Labneh after "squeezing" the packaging container; c: degree of whey syneresis when the Labneh was broken; d: no sign of syneresis when UF Labneh was broken with spoon.

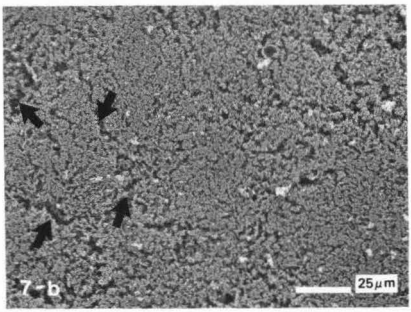
SEM examination of all Labneh at higher magnification suggests that the protein matrices are composed of casein particle chains and clusters; however, the lactic acid bacteria became apparent. The micellar chains were short to medium and the clusters were relatively small. The protein matrices appeared to be slightly influenced by the effect of smoothening of the product and the level of protein in Labnehs should not be overlooked (Fig. 3). The resulting matrices of the UF Retentate Labneh, UF Labneh and traditional Labneh that were smoothened were slightly less compact and more open than the matrices of the same types of Labneh before the smoothening stage. An illustration is shown in Fig. 9. The more open matrices were due to the formation of larger "pores" possibly as a result of the mechanical action of the lactic curd homogeniser resulting in re-clustering of the casein micelles. The most compact matrix appeared in traditional Labneh which was not smoothened and contained the highest level of protein.

The relationship between the total solids content and the density of the protein matrix was difficult to assess by visual examination of the micrographs presented, because the differences in the densities of the matrices were not as great as those found by Harwalkar and Kalab (1983) in yoghurts which were made from reconstituted nonfat dry milk and contained 10 to 30% total solids. The differences in the total solids contents









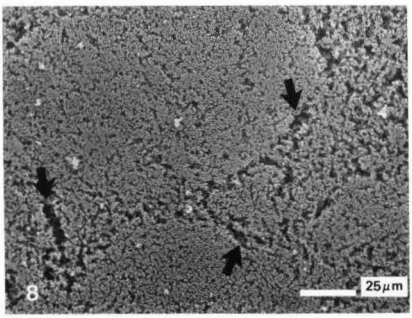


Fig. 6. UF Retentate Labneh before (a) and after passage through a lactic curd homogeniser (b). The uniform structures are the result of using homogenised milk retentate to produce the Labneh.

Fig. 7. UF Labneh before (a) and after (b) the homogenisation stage. Small hollow protein lumps (L) were occasionally seen in the UF Labneh before homogenisation. Passing the same product through the lactic curd homogeniser led to separation (arrows) of fluffy areas.

Fig. 8. Microstructure (SEM) of traditional Labneh that has been homogenised. Separation of fluffy areas (arrows) is clearly noticeable.

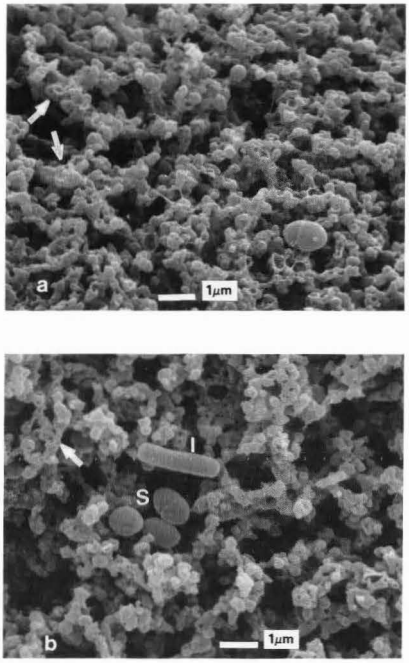


Fig. 9. Traditional Labneh before (a) and after (b) passage through a curd homogeniser. Separation of fluffy areas (arrows) is clearly noticeable. I: Lactobacilli; S: Streptococci.

between the UF Retentate Labneh and the traditional Labneh were insufficient to make the differences in the densities of the protein matrices apparent. Digital image analysis of many micrographs of the Labnehs under study would be necessary to establish such a correlation.

There was evidence of cavities present in the protein particles both before and after the homogenisation stage (Figs. 9a and 9b, respectively). The reason for the development of such cavities may be understood from the examination of the samples by TEM. In thin sections, minute fat particles produced from original fat globules as the result of the homogenisation of the milk or retentate are shown to be embedded in the casein matrix (Fig. 10). Occasionally, some fat globules as large as 5 µm in diameter passed through the curd homogeniser intact as is evident in Fig. 11. Fig. 12 shows a fat globule, 0.5 µm in diameter, with the fat globule membrane intact whereas in Fig. 13, a fat globule of a similar dimension has been ruptured.

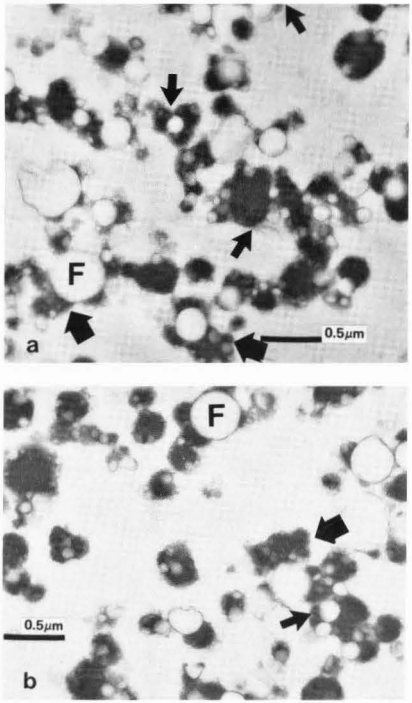
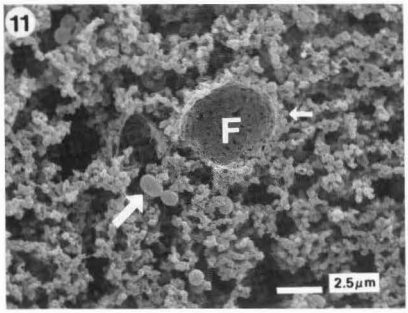
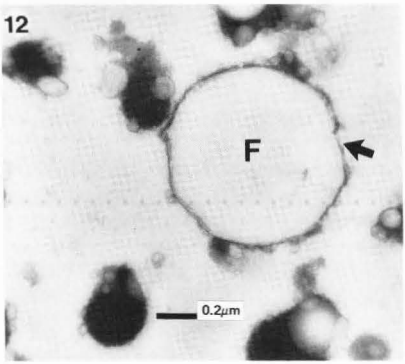
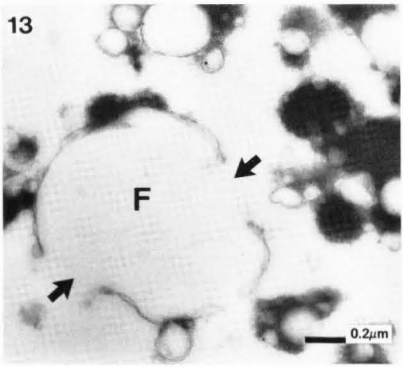


Fig. 10. TEM of traditional Labneh before (a) and after passage through a lactic curd homogeniser (b).
Minute fat globules (small arrows) are embedded in the protein, larger fat globules (F) are surrounded with casein particles (large arrows). The casein particle chains and clusters are larger before smoothening (a) than after it (b).

TEM examination of all the Labnehs showed chains of agglomerated casein particles and fat globules. Several samples of each Labneh suggest that the casein particle chains were shorter and the clusters were smaller in Labnehs which were smoothened by passage through a lactic curd homogeniser. This difference may be evident from Figs. 10a and 10b which are shown as an example, although one must be aware of the possibility that structures which appear to be small clusters, may in fact be cross sections of long chains (Kalab et al., 1976). In addition all the Labnehs showed some evidence of micelle fusion before smoothening (Fig. 10a).







The microstructure of Labneh markedly differs by the presence of fat and the distribution of the fat particles incorporated in the protein matrices, from the microstructure of yoghurt (Kalab et al., 1983; Harwalkar and Kalab, 1983) which is made from nonfat or low-fat milk. Another difference is the density of the protein matrix which reflects the higher protein content in Labneh than in yoghurt.

In conclusion, the differences in the microstructure of Labnehs made by three different procedures were subtle. Irrespective of whether the Labnehs obtained by culturing whole milk or homogenised milk retentate were smoothened, the protein matrices were relatively uniform and consisted of casein particle chains and clusters. However, the casein particle chains in Labnehs smoothened by the passage through a lactic curd homogeniser appeared to be somewhat shorter than in the unsmoothened Labnehs.

It is recommended that the lactic curd homogeniser should be employed to smoothen the traditional Labneh. In view of the shearing effect of such processing and to minimise the rheological changes, for example in UF Labneh, the homogeniser head No. D-280 should be used rather than No. D-170. Further work is still required to establish the effect of such processing on the structure of Labneh. The process of smoothening may not be necessary if the UF Labneh was cooled quickly after concentration by using a scraped surface cooler rather than cooling slowly in bulk.

Acknowledgements

The authors thank Dr. H.E. Modler for useful comments, Mr. A.S. Chehade, Mr. M.A. Mahdi, Mrs. Isobel Hamilton, Mrs. Paula Allan-Wojtas and Miss Gisele Larocque for skillful technical assistance. Electron Microscope Centre, Research Branch, Agriculture Canada in Ottawa provided facilities. Contribution 815 from the Food Research Centre in Ottawa.

Fig. 11. Microstructure (SEM) of fat globule membrane residue in Labneh. Occasionally, a medium-size fat globule (F) is left intact following the passage of the Labneh through the lactic curd homogeniser. Extraction of fat reveals the fat globule membrane residue (small arrow), large arrow points to streptococci.

Fig. 12. A small fat globule (F) with the fat globule membrane intact (arrow) passed through the lactic curd homogeniser.

Fig. 13. Passage through the lactic curd homogeniser ruptured the fat globule membrane (arrow) of a fat globule (F).

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Discussion with Reviewers

D. Holcomb: Are the authors confident that the relatively large samples (7 x 10 mm cylinders) were completely fixed, i.e., that glutaraldehyde had penetrated the interior of the samples?

Authors: As the SEM micrographs show, the samples were quite porous and, therefore, easily penetrated by aqueous glutaraldehyde. In addition, extended fixation taking several days before the samples were received for electron microscopy was taken into consideration. On arrival, the samples appeared to have uniform colouration in cross sections while they were trimmed into smaller prisms. (Allan-Wojtas and Kalab, 1984).

D. Holcomb: A goal of this sort of research might be to establish relationships between rheology and microstructure. However, the authors find that "on the basis of consistency, elasticity and susceptibility to syneresis" UF Retentate Labneh is somewhat different from the other Labnehs, while, on the basis of electron microscopy "all Labneh samples were, in general, similar ....." In light of these observations, do the authors feel that rheology-microstructure correlation is an attainable goal?
Authors: In our opinion, the inability to find a correlation between rheology and microstructure in Labneh does not mean that there is a total absence of any relationship. Gavaric et al. (1989), for example, reported that a correlation between firmness and microstructure of milk retentate gels obtained by using proteases of various origins was noticeable only when thin sections of the gels were examined at a high magnification. Gels consisting mostly of casein micelle chains were firmer than gels consisting mostly of casein micelle clusters. Only persistent structural and rheological studies of various milk products will reveal whether correlations between these two parameters exist.

E. Parnell-Clunies: Homogenisation (smoothening) appeared to create a more open protein matrix (Fig. 9). Was this a temporary effect or did the authors observe the re-appearance of the more compact network with time (e.g., 3 weeks post manufacture?). If so, was this re-aggregation accompanied by syneresis?
Authors: Passage of curd through a homogeniser breaks the curd granules into minute particles. Although the finished product appears to be smoother by sensory evaluation than the original curd, electron microscopy reveals the existence of the minute particles composed of casein micelle chains and clusters. At the same magnification, the microstructure of the larger curd grains appears to be more uniform than the homgenised curd. This phenomenon is similar to that observed in stirred yoghurt (Kalab et al., 1975) or homgenised cream cheese (H.W. Modler, personal communication). The structure of Labneh was not studied again after a prolonged period of time.

D.G. Pechak: What is the purpose of defatting the samples in chloroform? What is the advantage of defatting and/or what is the disadvantage of not defatting samples?
Authors: Fat particles present in any dairy product may be retained in the samples or removed from them prior to conventional scanning electron microscopy, i.e., the examination of dried samples at ambient temperature. In order to retain the fat in the samples, it must be thoroughly fixed to prevent unintentional extraction which may occur while the samples are dehydrated in ethanol and critical-point dried from liquid carbon dioxide. The fat may be fixed using an imidazole-huffered osmium tetroxide solution (Allan-Wojtas and Kalab, 1984). The advantage of this procedure is that it shows the presence of the fat particles in the product under study. This may be important if droplets of the aqueous phase (water, whey) and/or air cells are also present (Gavaric et al., 1989). However, micrographs of samples having a relatively compact protein matrix in which the fat has been retained, are more difficult to evaluate for the distribution of the fat particles because the freeze-fractured surfaces appear to be compact and flat (Kalab and Modler, 1985). Extraction of the fat using chloroform prior to freeze-fracturing of the samples impregnated with ethanol removes all fat residues which may otherwise be left in the samples if this extraction is omitted and, thus, prevents the development of artefacts (Kalab, 1984). The distribution of fat in samples extracted with chloroform is easy to evaluate because it relates to the void spaces in the protein matrix initially occupied with the fat. In addition, the presence of fat globule membranes or their residues may be noticeable in the micrographs of milk products such as natural cheese which contain intact fat globules as opposed to products such as process cheese in which the initial fat globule membranes had been removed from the fat globules by processing (Caric et al., 1985). In conclusion, retention as well as extraction of fat has advantages and disadvantages.

D.G. Pechak: How common were the protein aggregates? You state "occasionally" in the text but your micrograph shows three in one field of view? If such structures are as common as the micrograph implies then they would definitely affect the texture and water binding characteristics.
Authors: There is no discrepancy between the statement that the aggregates were seen only occasionally and the micrographs showing 3 aggregates within one field of view. A large area of the freeze-fractured planes was examined and the aggregates were found to be quite rare but similar to each other. A micrograph, in which 3 such aggregates are featured (a rare occasion) was selected to show their nature.

D.G. Pechak: Is it possible that the cracks or separations that you describe as fluffy areas are a result of one odd preparation during the cryo-fracture step? How many preparations of this sample showed similar structures and were the spacings or cracks also seen at the light microscope level in "thick sections" of the Spurr's embedded material, which did not receive the freezing step?
Authors: Dehydration of samples fixed in glutaraldehyde and their impregnation with absolute ethanol prior to freeze-fracturing prevents the development of artefacts which are associated with ice crystal formation in hydrated samples. This report is not based on the observation of one odd preparation. The separations were a common feature unlike the occasional occurrence of protein aggregates dealt with in the previous question. No sections of the embedded samples were examined by light microscopy.

Y. Kakuda: Were the hollow aggregates seen only in the UF Labneh? Any ideas on how these structures were formed? Could these hollowed structures be responsible for the fluffy areas seen after the Labneh was smoothened?
Authors: Yes, the hollow aggregates were seen only in the UF Labneh. We have no idea about how they were formed but because of their low occurrence, they probably do not contribute to the structure of the smoothened Labneh.

Y. Kakuda: Were there any pumping or fouling problems during the UF treatment of the milk or yoghurt?
Authors: No, the problem of fouling during UF treatment of the milk was not observed because we were only handling small quantities; however, during the UF of yoghurt the permeate flux rate was reduced as the product became thick and towards the final stages of concentration the outlet valve had to be fully open to avoid any blockages of the membrane.

Y. Kakuda: Is it possible that the heat treatment of the retentate (compared to unconcentrated milks) was insufficient to produce the desired textural properties in the UF Retentate Labneh?
Authors: No, the heat treatment of both types of milks was sufficient, i.e. 90°C for 5 min, and the use of higher temperatures may cause other problems that can affect the texture of the product (Tamime and Robinson, 1985, 1988a).

L. Krsev: Why is the lactic curd homogeniser recommended to be used in Labneh manufacture?
Authors: It is essential that the lactic curd homogeniser is used to smoothen the traditional Labneh in order to remove the evidence of lumps in the product. As mentioned in the text such process may not be required if the UF Labneh is cooled directly after ultrafiltration.

L. Krsev: The obtained results show negative effect of the lactic curd homogeniser when using the homogeniser head No D-170. What is the reason you think that the homogeniser head No. D-280 would be better?
Authors: The homogeniser head No. D-280 consists of lower number of grooves as compared with D-170 and hence the sheering effect on the Labneh will be reduced. As a result, the drop in the consistency measurement after the homogenisation stage will not be great and the structure of the ALM homogeniser head has been published elsewhere (Tamime and Crawford, 1984). Despite the slight reduction in the firmness of the Labneh after it was passed through the lactic curd homogeniser, all the different types of Labneh appeared smoother and improved the overall shine of the product.

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