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RHEOLOGICAL PROPERTIES OF ACIDIFIED HEATED SKIM MILK AS AFFECTED BY THE ADDITION OFWHEY PROTEIN CONCENTRATES

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ABSTRACT

The effect of heat treatment and addition of whey protein concentrates (WPC) solution (3% protein) on the rheological properties of acid skim milk gels was investigated. Milk samples were pasteurized, boiled and UHT treated. WPC was added to heated skim milk at ratios of 0, 5, 10, 15, 20 and 25% v/v. Gel formation was followed using thrombelastograph to determine the gelation time (r) and curd firmness (K_{20}). Coaxial viscometer was used to determine the changes in viscosity during acidification. Results indicated that increasing the addition of WPC reduced the gelation time (r) for both unheated and heated milk samples. The time required to get curd firmness was increased with increasing WPC added for unheated and pasteurized milk. Moreover, gel formation was lost in boiled and UHT milks. The viscosity of acidified gels decreased with increasing the added WPC. The viscosity of acidified boiled skim milk showed decreased values and weak gel. UHT treated skim milk failed to form firm curd and its viscosity was affected slightly by acidification.
Keywords: Whey protein concentrates (WPC), Cow skim milk, Heat treatment, Gelation time, Curd firmness,Viscosity.

INTRODUCTION

In acid milk gels, such as yoghurt, the overall visual appearance, microstructure and rheology are important attributes that contribute to the overall sensory perception and functionality of these products. The heat treatment of milk is one of the most important processing steps affecting both the texture and rheological properties of these products (Robinson & Tamime 1993; Mullvihill & Grufferty, 1995). Pasteurization, boiling and sterilization are used extensively for the preservation of milk by and also to modify the functional properties of many dairy products. Heat processing leads to many changes in milk including denaturation of whey proteins and their interaction with casein micelles and with each other.

The rheological properties of acid milk gels formed by acidification with Glucono-Delta-Lactone (GDL) have been reported (Arshad *et al.* 1993; Cobos *et al.* 1995; Van Vliet & Keetels 1995 and Farrag *et al.* 2001). Also, the effect of heat treatment on the small and large deformation, rheological properties of acid milk gels formed with GDL was discussed (Lucey *et al.* 1997).

Whey protein concentrates (WPC) are widely used as food ingredients in the production of variety of dairy products, meat and beverages (Cayot and Lorient, 1997) as it has a good nutritional value. It is absorbed, utilized and retained better which make it beneficial to people consuming it in their diet. Moreover, WPC has a good water holding capacity and can improve the rheological properties of food products (Maubois and Ollivier 1997).

The objective of the present study was to evaluate the rheological properties of GDL-induced gels from heated cow skim milk mixed with whey protein concentrate.

MATERIALS AND METHODS

MATERIALS

1- Skim milk

Fresh cow skim milk samples (9.1% TS, 2.8% TP) were pasteurized and boiled with 10 sec. holding time, then rapidly cooled to the gelation temperature 40°C while UHT skim milk was obtained from Enjoy Co. (8.16% TS, 2.7% TP). Raw, pasteurized, boiled and UHT skim milk was adjusted to pH 6.6 before acidification.

2- Preparation of Whey Protein Concentrates

Edam cheese whey was obtained from Arab Dairy Co. (Kaha , Kaliobia, Egypt). Whey was ultrafiltered at 45°C using a Carbosep pilot plant (Orelis – France) equipped with 6.3 m^2 of inorganic membrane at inlet pressure of 5 bar. Ultrafiltration was continued to a concentration factor of 20 (refractometer reading 16% TS). The retentate was diluted with permeate to obtain whey protein concentrates containing 3% protein before adding to skim milk.

3- Preparation of samples:

Whey protein concentrate containing 3% protein was added to heated skim milk (warmed at 40°C) at the ratio of 5, 10, 15, 20 and 25% (v/v), stirred for 5 sec and acidified with 2% GDL (Pfizer Co.), immediately before measurement of gelation and viscosity.

METHODS

1- Gelation measurements

The gelation time and curd firmness were determined using thrombelastograph (Hillige, Germany) as described by Abd El-Salam *et al.* (1996). The gelation time (r) is the time lapces from the addition of GDL until the formation of acid induced gel commences while thecurd firmness (K_{20}) is the time from the first sign of gel formation until the width of the ampiltude is 20 mm. Longer time for K_{20} indicate weaker gel. A parallel experimental was carried out under the same conditions and changes in pH was recorded.

2- Viscosity measurements

The changes of viscosity during gel formation versus time were followed using coaxial viscometer (Bohlin V88, Sweeden) as described by El-Din *et al* (2000). The measuring system was C30 with 60 sec intervals and shear rate of 570 1/s at 40°C.

All experiments were carried out in three replicates and mean values were reported.

RESULTS AND DISCUSSION

Gelation time (r) of acidified heated skim milk as affected by adding WPC is Illustrated in Fig. 1. Addition of WPC to heated skim milk reduced its gelation time (r). Pasteurized skim milk showed highest gelation time with or without added WPC followed by UHT treated, boiled and unheated skim milk.

The gelation time was 2130, 1620, 1350, and 1050 sec for pasteurized, UHT, raw and boiled in the treatments without adding WPC, then decreased to 1050, 810, 570 and 780 in case of adding 25% WPC in the same order.

Table (1): Percentage decrease in gelation time (r) of acidified raw and heated skim milk with added WPC.

% added WPC	Unheated	Pasteurized	Boiled	UHT
5	11.11	18.18	5.71	7.41
10	33.33	31.17	11.43	22.22
15	37.77	33.77	25.71	25.92
20	55.55	40.26	25.71	48.30
25	57.77	45.54	33.33	50.00

Table (1) shows the percentage decrease in gelation time (r) for acidified raw and heated skim milk with added WPC. These results clearly indicated that increasing the concentration of WPC reduced the gelation time (r). Acidified pasteurized skim milk showed highest reduction in gelation time (r) of 18.18% compared with other samples when 5% WPC were added. The structure ofgels made from unheated skim milk was reported to be irregular with area of dense protein clusters while gels made from heated skim milk appeared more regular with clearly defined pores and thinner, straight strands compared to unheated skim milk, (Lucey *et al.* 1999).

The pH recorded at gelation time (r) of acidified raw and heated skim milk is shown in Fig. 2. Increasing the concentration of WPC added increased slightly the pH values at gelation time of raw milk. It was 4.93, 5.13, 5.17, 5.20, 5.25 and 5.29 with 0, 5, 10, 15, 20 and 25% of added WPC. However, addition of WPC did not affect the pH values at (r) for acidified heated milks. Johanna and Skelte (2003) reported that acid gels prepared from heated whey protein-depleted milk had longer gelation time and lower gelation pHs than those prepared from heated skim milk.

Increasing the quantity of WPC added to skim milk increased the time of curd firmness (K_{20}) of acidified raw and pasteurized skim milk as shown in Fig. 3. Curd firmness time increased from 930 to 1770 sec with increasing WPC added from 0 to 25% for unheated skim milk, and it was 1230, 1380, 1830, 1890 and 2070 sec with 0, 5, 10, 15 and 20% WPC added to pasteurized skim milk. Moreover, no firm coagulum was observed for acidified boiled and UHT skim milk even the pH was dropped to 5.0. Onwulata *et al* (2003) reported that gel strength was lost of heated WPC at 75°C and 100°C.

The percentage increase in the time required to reach firm curd (K_{20}) of acidified raw and heated skim milk with added WPC are shown in Table 2. It illustrates that decreasing the casein/whey protein ratio produced larger aggregates which gave more weak gels (Guyomarch *et al*, 2003).

Table (2): Percentage increase in curd firmness time (K_{20}) of acidified raw and heated skim milk with added WPC.

% added WPC	Unheated	Pasteurized	Boiled	UHT
5	25.81	12.20	Ng	ng
10	25.81	48.78	Ng	ng
15	32.26	53.66	Ng	ng
20	32.26	68.29	Ng	ng
25	90.32	ng	Ng	ng

ng: No gel formation

Fig. 1: Gelation time (r) of heated skim milk acidified with 2% GDL/40°C as affected by added WPC.

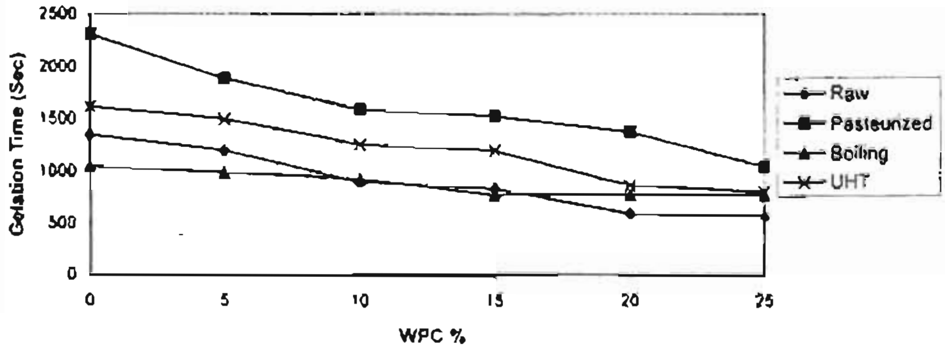


Fig. 2: pH changes at gelation time (r) of heated skim milk acidified with 2% GDL/40°C as affected by WPC added.

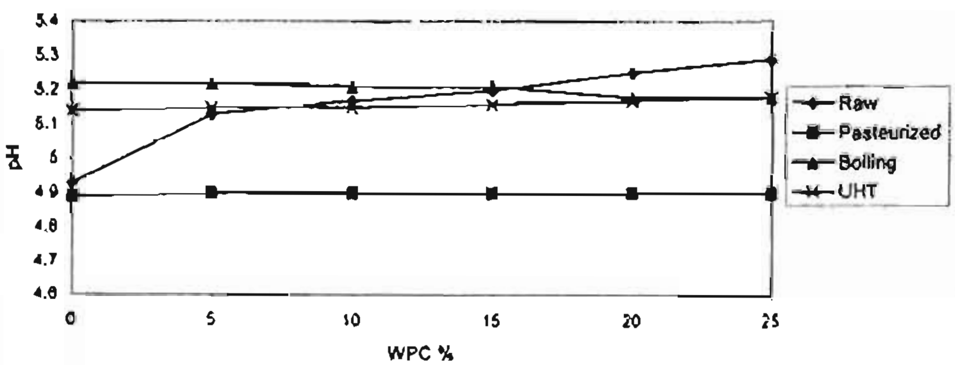


Fig.3: Curd firmness (K20) of heated skim milk acidified with 2% GDL/40°C as affected by WPC added.

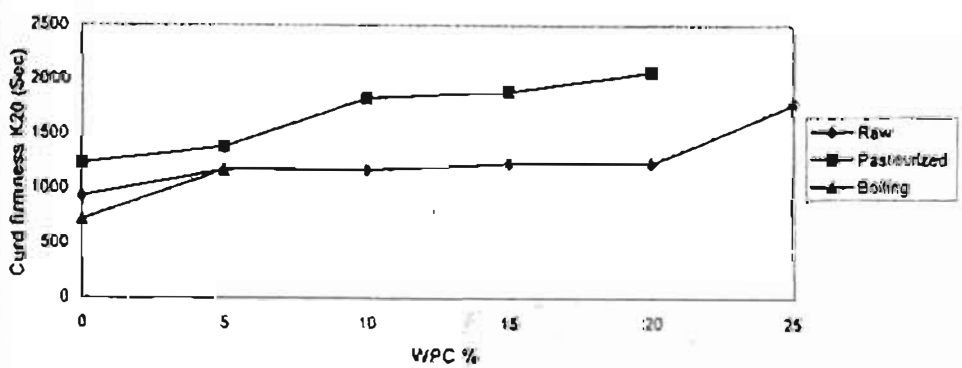


Table (3) shows the changes of pH values at K_{20} of acidified raw and heated skim milk with added WPC. Acidified skim milk gels formed at higher pH and lower temperature are stronger and show less susceptibility to syneresis. Unheated milk serum caseins play a key role in gelation kinetics and characteristics of the final gel formed. (Vasbinder *et al*, 2003).

Table (3): Changes in pH values at curd firmness time (K_{20}) of acidified raw and heated skim milk with added WPC.

% added WPC	Unheated	Pasteurized	Boiling	UHT
0	4.55	4.55	5.01	ng
5	4.60	4.60	5.03	ng
10	4.68	4.60	ng	ng
15	4.72	4.60	ng	ng
20	4.84	4.63	ng	ng
25	4.90	ng	ng	ng

ng: No gel formation

The changes of the apparent viscosity of acidified heated skim milk are shown in Fig. 4. Unheated acidified skim milk gel showed highest viscosity values of 226 mPas after 490 sec from onset acidification, and then decreased as a result of deformation of the gel. Both pasteurized and boiled milks showed similar behaviour during gel formation. On contrast the viscosity of UHT skim milk was not affected by acidification showing the highest viscosity values of 134 mPas at onset of acidification which slightly changed during gel formation.

Addition of 5% WPC decreased the viscosity values of acidified unheated skim milk gel formed (Fig. 5); it was 210 mPas after 490 sec. Pasteurized and boiled skim milk gels showed low viscosity values of 142 and 89.7 mPas after 610 sec of acidification. UHT skim milk did not show any change in its viscosity after acidification.

Increasing the percent of added WPC to 10 and 15% and its effects on the changes in viscosity for acidified heated skim milk are shown in Fig. 6 and 7. Unheated skim milk reached highest viscosity (gel firmness) after 370 sec from the onset of acidification and decreased from 232 to 172 mPas with increasing the concentration of WPC added from 10 to 15%. Boiled skim milk with 10 or 15% WPC showed a decrease in the viscosity values during gel formation. UHT skim milk acidified by 2% GDL failed to form gel with and showed unchanged viscosity versus time relationship.

Further increase of added WPCup to 20 and 25% and its effect on gel formation for heated skim milk are shown in Fig. 8 and 9, respectively. Acidified unheated skim milk showed high viscosity values of 123 mPas after 370 sec from the onset of acidification with added 20% WPC but decreased to 101 mPas with increasing WPC to 25% after the same time. Both boiled and UHT skim milk failed to form a gel with increasing the quantity of WPC added, which may be due to the presence of large water containing voids between the casein aggregates.

Generally the viscosity results indicated that gellation occurred more quickly at higher pH and with decrease the quantity of WPC added. These results were in agreement with that of Kelly and Kennedy (2001).

Fig. 4: Viscosity of skim milk gels acidified with 2% GDL/40°C as affected by heat treatment.

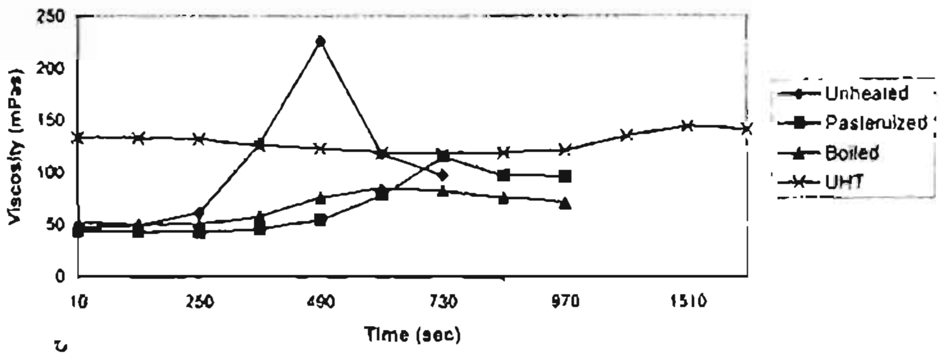


Fig. 5: Viscosity of heated skim milk gels acidified with 2% GDL/40°C as affected by adding 5% WPC.

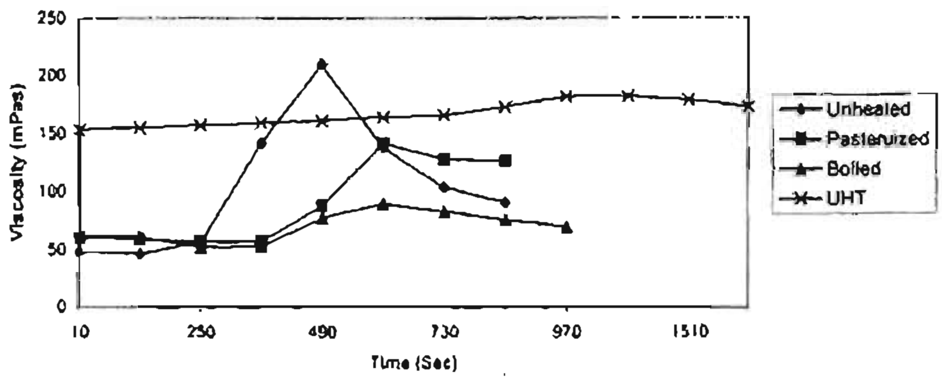


Fig. 6: Viscosity of heated skim milk acidified by 2% GDL/40°C as affected by added 10% WPC.

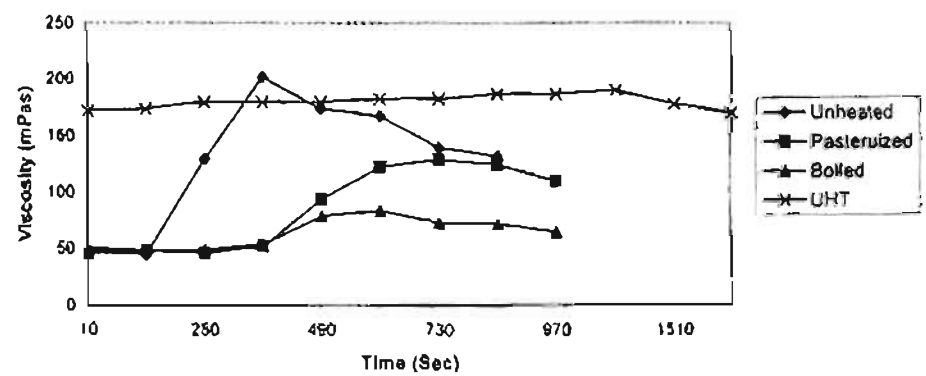


Fig. 7: Viscosity of heated skim milk acidified by 2% GDL/40°C as affected by added 15% WPC.

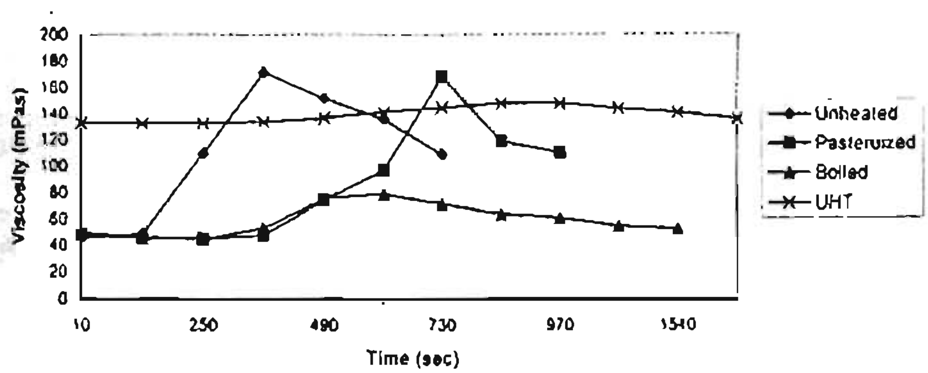


Fig 8: Viscosity of heated skim milk acidified by 2% GDL/40°C as affected by added 20% WPC.

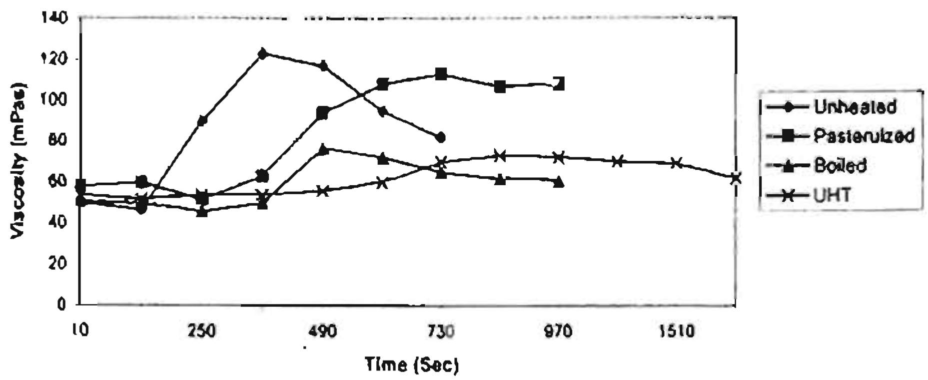
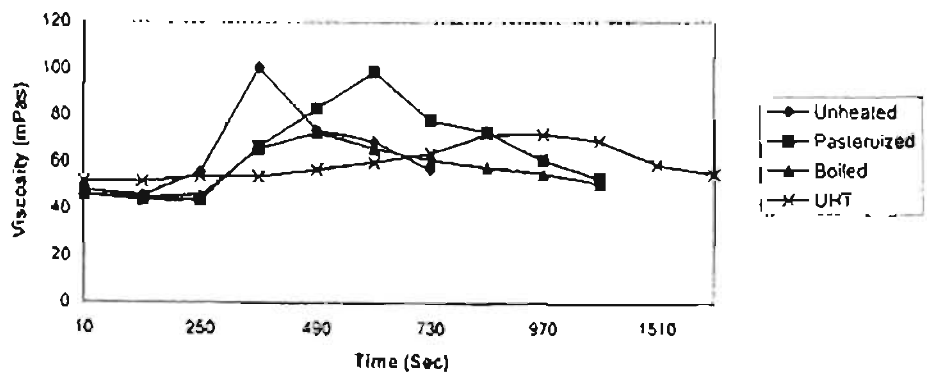


Fig. 9: Viscosity of heated skim milk acidified by 2% GDL/40°C as affected by added 25% WPC.



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الخواص الريولوجية للجل الحامضي الناتج من إضافة مركزات بروتينات الشرش للبن البقري الفرز والمعامل حراريا.

عاطف فراج – نادية محمد شاهين و هالة محمد فخر الدين
المركز القومى للبحوث – قسم الالبان

يهدف البحث إلي دراسة تأثير المعاملات الحرارية التي تجري علي اللبن البقري الفرز والتي تشمل البسترة والغلي والمعامل بالحرارة فوق العالية (UHT) وكذلك إضافة مركزات بروتينات الشرش بنسبة صفر، ٥، ١٠، ١٥، ٢٠ ، ٢٥% على الخواص الريولوجية للجل الحامضي الناتج بإضافة ٢% GDL عند ٤٠°م باستخدام جهازي ال Thrombelastograph لتقدير وقت بداية تكون الجل وقوة الجل وكذلك جهاز اللزوجة Viscometer لتتبع التغيرات في اللزوجة أثناء تكون الجل وقد خلصت الدراسة إلى النتائج التالية:

- قل الوقت اللازم لبداية تكون الجل (r) وذلك بإضافة بروتينات الشرش وذلك في اللبن الغير معامل حراريا وكذلك المبستر والمغلي والمعقم.
- زاد الوقت اللازم لتكوين جل متماسك K_{20} مع زيادة نسبة بروتينات الشرش المضافة لكل من اللبن الغير معامل حراريا واللبن المبستر.
- زاد الوقت اللازم لتكون خثرة متماسكة للبن المغلي عند إضافة ٥% بروتينات الشرش ووصلت هذه الزيادة إلى ٦٥,٥% مقارنة باللبن الغير مضاف إليه بروتينات الشرش بينما لم تتكون خثرة متماسكة عند زيادة بروتينات الشرش المضافة إلى ١٠% وحتى نسبة إضافة ٢٥%.
- لم تتكون خثرة متماسكة بالتحميض (٢% GDL)) لكل من اللبن المغلي أوالمعامل بالحرارة فوق العالية UHT سواء المحتوي أو غير المحتوي على بروتينات الشرش.
- اظهرت نتائج اللزوجة قيما مرتفعة عند بداية تكون الجل في اللبن المحمض الغير مضاف إليه بروتينات الشرش قلت بعدها مع زيادة نسبة بروتينات الشرش المضافة وذلك لكل من اللبن الغيرمعامل حراريا والمبستر والمغلي.
- أظهر اللبن المعامل UHT المحمض قيما مرتفعة للزوجة عند إضافة ٥ ، ١٠، ١٥ % بروتينات الشرش ثم انخفضت بعدها بشكل ملحوظ مع تقدم الزيادة في نسبة بروتينات الشرش المضافة إلى ٢٠ ، ٢٥%.
- لم تتكون خثرة متماسكة للبن المعامل حراريا UHT نتيجة التحميض بال GDL حيث لم تتأثر نتائج اللزوجة المتحصل عليها أثناء تكون الجل.
- دلت النتائج بوجه عام على أن إضافة بروتينات الشرش والمعاملات الحرارية العالية تعمل على إنتاج جل ذو خثرة ضعيفة تصل إلي حد عدم تكون الجل نهائيا مع التقدم في زيادة نسبة بروتينات الشرش المضافة أو ارتفاع المعاملات الحرارية . وبالتالي يمكن إضافة بروتينات الشرش إلي اللبن المبستر لانتاج منتجات تتطلب وجود لزوجة عالية لاتصل إلى حد تكون الجل المتماسك مثل إنتاج اليوجهورت واللبن الرايب والجبن المطبوخ القابلة للفرد.