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Rheological Behaviour of Agharan Contains Different Concentration of Whey Powder, Starch and Gum Arabic

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Abstract: The Agharan is a fermented concentrated camel milk in Iran. Agharan is prepared by gathering the top layer of fermented camel milk. The aim of the present research is to study the effect of Whey Powder, Gum arabic and starch on rheological properties of Agharan. Effect of these materials in 0.05, 0.1 and 0.15% at different rpms (30, 40, 50, 60, 70, 80, 90, 100, 105, 120, 135, 140, 150, 160, 180, 200) on rheological properties of Agharan at 24°C studied. Results with Mitschka method reavealed that all samples have shear thining behaviour. All samples showed the rather similar decrease in apparent viscosity with increasing the shear rate and in all concentrations of Agharan contain gum arabic, viscosity decreased slightly in comparrison to control. In contrast, Agharan contains 0.15% whey powder has sharp slope. The level of decrease was dependent on the level of whey, starch and gum arabic added. The highest apparent viscosity values were recorded for Agharan contains 0.1 ,0.05% starch (3520.7, 2678.4) and the lowest for Agharan contains 0.15% gum arabic (823.25). Results of this research showed starch, whey powder and gum arabic can alter some rheological properties of Agharan and accordingly can use in dairy industry.

Key words: Aghara, fermented camel milk, starch, shear thining, Iran

INTRODUCTION

Camel is a useful animal which many years ago domesticated by human and used its milk, meat, skin, wool and so one. Fermented camel milk is one of the 3500 traditional fermented food exist in the world (Anonymous, 1999) that believed to be one of the oldest fermentation products known to humans, originating in the Middle East and Africa and is consumed by some people in pastoralis regions (Chandan *et al*., 2006; Tamime and Robinson, 1999).

Camel milk and fermented camel milks are nutritious foods because has medicinal properties and in many region used against some diseases (Rao *et al*., 1970; Akhundov *et al*., 1972; Sharmanov *et al*., 1978; Gast *et al*., 1969). Agharan, also is a fermented camel milk produced in some area in Golestan Province, Iran that in Turkmen dialect called Agharan. It is prepared by gathering the thin layer of fermented camel milk and has a nutritious value and serve especially as a breakfast.

Most of whey protein is lost in the drainage without any benefit (Morr and Foegeding, 1990). The environmental pollution and high cost of disposing it, also the high nutritional value (Damodoran, 1996) and low cost of whey encouraged scientists to utilize it as an excellent food component in the foods (Dickinson, 1997).

Functional properties of whey proteins, such as emulsifying, water/fat holding, extening shelf-life, foaming, thickening and gelling properties (Hall and Iglesias, 1997), also nutritional value (Tipton *et al*., 2004), make them interesting to be used as a food ingredient in conjunction fermented milks (Huffman, 1996). Several studies have used whey powder in yoghurt making which leads to provide better consistency, texture and creaminess to the product.

Plant hydrocolloids used in foods for improve texture and stability. Gums are polysaccharides that classified according to their origin (Igoe, 1982). Gum arabic, also called Acacia Gum is the natural exudate from the Acacia Senegal which have high molecular weight consisting of branched arabinogalactan heteropolymers (Anderson *et al*., 1983; Street and Anderson, 1983). The gums have the ability to control the rheology and texture throughout the stabilization of emulsions, suspensions, foams and starch gelatinization (Rosell *et al*., 2001).

Gum arabic also contains proteins (2%). Uronic acid in Gum arabic is responsible for the polyanionic character of it with a pHi around 3 (Kravtchenko, 1997; Wang and Qvist, 2000). Starch is one of the most used thickener in dairy products due to improve mouthfeel, prevent syneresis and low cost when compared with other

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hydrocolloids (Foss, 2000). The aim of the present research, is to study the effect of the addition of different concentration of whey powder, gum arabic and starch on rheological properties of Agharan.

MATERIALS AND METHODS

Whey powder used in this study was a commercial product from golestan dairy industries company (PEGAH, Iran) with about composition of 11% protein, moisture 5%, total solids 95%, 1.5% fat and acidity (lactic acid) 0.12% as per manufacturer's data. Starch obtained from Merck Company (Germany). Agharan from one-humped camel (*Camelus dromedarius*) purchase from Bandar Torkman City in Golestan Province (Iran). Also, gum arabic used in this study. All the examinations carry out in the labratoary of Department of Food Science and Technology of Agricultural Science and Natural Resources University, Gorgan, Iran.

Preparation method of Agharan: For production of Agharan allowe to camel milk to quiet in a steady place at ambient temperature after it break into 2 phases, the solids are remove gently from the thin layer of coagulated milk that partially fermented. In fact, it is concentrated sour camel milk which in Turkmen dialect in Iran called Agharan. Total solids, pH and acidity (Dornic) of the Agharan used in this study were 20, 4.4 and 80%, respectively.

Addition of powders and mixing: About 3 levels of starch, whey powder and Gum arabic (0.05, 0.1 and 0.15%) were considered in this study. Powders were added to Agharan under gentle constant mixing with aid a Kitchen mixer for 1 min. Then the samples were kept at 4-5°C for 24 h before any tests were carried out. Before using gum arabic, first its solution was prepared by hydrating in distilled water, mixed with a magnetic stirrer for 24 h at 60°C, then added to Agharan and sample kept at 4-5°C for 24 h. A control batch (without whey protein, starch and gum arabic) was also mixed under similar conditions.

Rheological measurements: The apparent viscosity of the Agharan determined at 24°C at various shear rates (from 9.5-100 sec^{-1}) with the aid of a Brookfield RDVD-II, viscometer (Brookfield Engineering Laboratories, USA) using spindle No. 3 at different rpms (30, 40, 50, 60, 70, 80, 90, 100, 105, 120, 135, 140, 150, 160, 180, 200). For each sample 3 readings were taken and their means were reported.

The sample was placed in a 600 mL low form griffin beaker and a disc was inserted into the sample. To eliminate any time-dependent behavior, sample was subjected to pre-shearing until a constant torque was observed. Formal data collection of torque at various rotational speeds followed immediately. All data were collected at room temperature, approximately 24°C.

Table 1: Conversion factor for the spindles of the Brookfield R.V.T. viscometer (under standard measuring conditions)

	Spindle No.						
Factors	1	2	3	4	5	6	7
k_{at}	0.035	0.119	0.279	0.539	1.050	2.350	8.400
k_{ny}							
n = 0.1	1.728	1.431	1.457	1.492	1.544	1.366	1.936
0.2	0.967	0.875	0.882	0.892	0.907	0.851	1.007
0.3	0.705	0.656	0.656	0.658	0.663	0.629	0.681
0.4	0.576	0.535	0.530	0.529	0.528	0.503	0.515
0.5	0.499	0.458	0.449	0.445	0.442	0.421	0.413
0.6	0.499	0.404	0.392	0.387	0.382	0.363	0.346
0.7	0.414	0.365	0.350	0.343	0.338	0.320	0.297
0.8	0.387	0.334	0.317	0.310	0.304	0.286	0.261
0.9	0.367	0.310	0.291	0.283	0.276	0.260	0.232
1	0.351	0.291	0.270	0.262	0.254	0.238	0.209

Mitschka (1982), method tested with spindle No. 3. Values of a_i (on the torque dial from units 0-100) are converted to the (average) shear stresses τ_i (in pa) on spindle used by:

$$\tau_i = k_{at} a_i$$

Pairs of $\tau_i - N_i$ (rotational speed in rpm) valid for spindle are plotted in the log-log form. When this dependence is sufficiently close to a linear 1, the fluid under test is of the power-law type. The slope of the log τ_i-log N dependence in this case is equal to the flow index of the fluid or n. Using values of k_{ny} (n) for this flow index and spindle number, the corresponding values of the shear rates y_i (sec^{-1}) are then calculated as:

$$y_i = k_{ny}(n) N_i$$

The relevant pairs τ_i-y_i are assumed to be the points of the viscosity function of the fluid sample tested. Conversion factor for the method described by mitschka shown in Table 1.

Statistical analysis: The effects of concentration, N and shear rate on the apparent viscosity were studied. Related graphs and curves drown by Excel. A significance level of 0.05 was utilized for all analyses.

RESULTS

Viscosity measurements: After calculating the shear rate, shear stress and Aspparent viscosity (Table 2-5), established the related curves. The apparent viscosity of Agharan samples decreased with increase shear rate,

Table 2: Agharan without additives

Shear stress (Pa)	Shear rate (sec^{-1})	Apparent viscosity (Pa. sec)
19530	9.510	2053.60
19920.6	12.680	1571.00
24998.4	15.850	1577.20
29490.3	19.020	1550.50
33786.9	22.190	1522.60
37888.2	25.360	1494.00
41989.5	28.530	1441.70
45700.2	31.700	1441.64
47457.9	33.285	1425.80
52535.7	38.040	1381.00
57222.9	42.795	1505.80
57808.8	44.380	1302.59
61910.1	47.550	1302.00
66206.7	50.720	1305.33
73432.8	57.060	1286.94
80463.6	63.400	1269.14

Table 3: Agharan with different concentration of starch

Agharan contains 0.05% starch			Aghran contains 0.1% starch			Agharan contains 0.15% starch		
Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)
28123.2	10.50	2678.40	51754.5	14.70	3520.70	20311.2	9.510	2135.77
36130.5	14.00	2580.75	58394.7	19.60	2979.30	21873.6	12.680	1725.00
43161.3	17.50	2466.36	64058.4	24.50	2614.62	27732.6	15.850	1749.70
49410.9	21.00	2352.90	69331.5	29.40	2358.20	32810.4	19.020	1762.80
55269.9	24.50	2255.90	74018.7	34.30	2157.98	37497.6	22.190	1689.84
60738.3	28.00	2169.22	78510.6	39.20	2002.82	41989.5	25.360	1655.74
66011.4	31.50	2095.60	83197.8	44.10	1886.57	46286.1	28.530	1622.36
71089.2	35.00	2031.12	87299.1	49.00	1781.60	50387.4	31.700	1589.50
73432.8	36.75	1998.17	89838.0	51.45	1746.12	52340.4	33.285	1572.49
80268.3	42.00	1911.15	92767.5	58.80	1577.68	58004.1	38.040	1524.80
86322.6	47.25	1826.93	98821.8	66.15	1493.90	60543.0	42.795	1414.72
88080.3	49.00	1797.56	99993.6	68.60	1457.60	63081.9	44.380	1421.40
90814.5	52.50	1729.80	102141.9	73.50	1389.68	66402.0	47.550	1396.46
93744	56.00	1674.00	105657.3	78.40	1347.67	71870.4	50.720	1417.00
103313.7	63.00	1639.90	115227.0	88.20	1306.42	79682.4	57.060	1396.47
112492.8	70.00	1607.00	123234.3	98.00	1257.49	87103.8	63.400	1373.88

Table 4: Agharan with different concentration of gum arabic

Agharan contains 0.05% gum arabic			Agharan contains 0.1% gum arabic			Agharan contains 0.15% gum arabic		
Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)
36130.5	13.8	2618.15	34177.5	14.4	2373.430	34177.5	15.0	2278.50
40622.4	18.4	2207.74	38474.1	19.2	2003.860	38474.1	20.0	1923.70
44723.7	23.0	1944.50	42380.1	24.0	1765.840	42380.1	25.0	1695.20
48434.4	27.6	1754.87	45895.5	28.8	1593.600	46090.8	30.0	1536.36
52145.1	32.2	1619.40	49410.9	33.6	1470.560	49215.6	35.0	1406.16
55660.5	36.8	1512.51	52926.3	38.4	1378.290	52731.0	40.0	1318.27
59175.9	41.4	1429.37	56051.1	43.2	1297.470	55660.5	45.0	1236.90
62300.7	46.0	1354.36	58980.6	48.0	1228.760	58394.7	50.0	1167.90
63667.8	48.3	1318.17	60347.7	50.4	1197.370	59761.8	52.5	1138.32
68159.7	55.2	1234.77	64449.0	57.6	1118.900	63277.2	60.0	1054.62
71479.8	62.1	1151.00	67769.1	64.8	1045.820	66402.0	67.5	983.73
72261	64.4	1122.00	68745.6	67.2	1023.000	67378.5	70.0	962.55
76167	69.0	1103.87	72261.0	72.0	1003.620	71089.2	75.0	947.85
79096.5	73.6	1074.68	75190.5	76.8	979.000	74018.7	80.0	825.23
85346.1	82.8	1030.75	80854.2	86.4	935.810	79487.1	90.0	883.19
91205.1	92.0	991.36	86517.9	96.0	901.228	84955.5	100.0	895.55

Ss = Shear stress; Sr = Shear rate; A. vis = Apparent viscosity Pa = Pascal; Pa. sec = Pascal sec

Table 5: Agharan with different concentration of Whey powder

Agharan contains 0.05% whey powder			Agharan contains 0.1% whey powder			Agharan contains 0.15% whey powder		
Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)
19725.3	10.5	1878.60	30662.1	12.6	2433.50	20311.2	9.51	2135.77
20506.5	14.0	1464.75	35154.0	16.8	2092.50	28513.8	12.68	2248.72
21092.4	17.5	1205.28	39255.3	21.0	1869.30	34958.7	15.85	2205.60
22068.9	21.0	1050.90	42770.7	25.2	1697.25	40817.7	19.02	2146.00

Table 5: Continue

Agharan contains 0.05% whey powder			Agharan contains 0.1% whey powder			Agharan contains 0.15% whey powder		
Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)	Ss (Pa)	Sr (sec^{-1})	A. vis (Pa. sec)
26170.2	24.50	1068.17	46286.1	29.4	1574.350	47067.3	22.190	2121.10
30076.2	28.00	1074.15	49801.5	33.6	1482.180	52340.4	25.360	2063.90
33591.6	31.50	1066.40	52926.3	37.8	1400.160	57222.9	28.530	2005.70
37107	35.00	1060.20	55855.8	42.0	1329.900	62105.4	31.700	1959.16
40427.1	36.75	1100.00	57222.9	44.1	1297.570	64253.7	33.285	1930.41
41598.9	42.00	990.45	60738.3	50.4	1205.125	71089.2	38.040	1868.80
45114.3	47.25	954.80	65620.8	56.7	1157.330	76948.2	42.795	1798.85
49996.8	49.00	1020.34	67378.5	58.8	1145.900	78510.6	44.380	1769.00
52145.1	52.50	993.24	70503.3	63.0	1119.100	82221.3	47.550	1729.15
55465.2	56.00	990.45	73432.8	67.2	1092.750	85541.4	50.720	1686.54
58590	63.00	930.00	79487.1	75.6	1051.410	91986.3	57.060	1612.10
64839.6	70.00	926.28	85736.7	84.0	1020.670	101556.0	63.400	1601.83

Ss = Shear stress; Sr = Shear rate; A. vis = Apparent viscosity Pa = Pascal; Pa. sec = Pascal sec

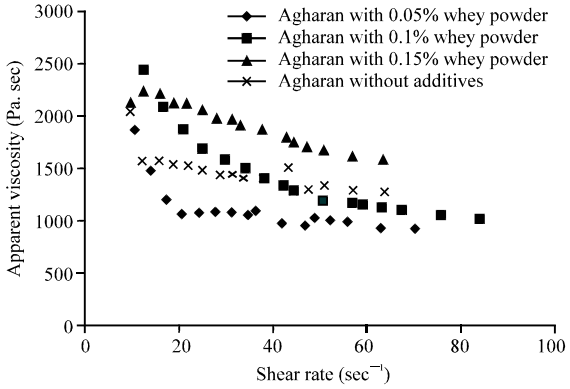

Fig. 1: Apparent viscosity versus shrear rate for Agharan contains different concentration of whey powder

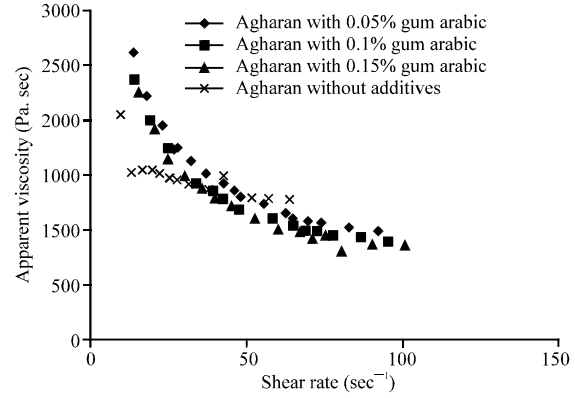

Fig. 2: Apparent viscosity versus shrear rate for Agharan cotains different concentration of gum arabic

indicating a non-newtonian fluid and showed shear-thinning behavior that characterized by flow behavior index values of <1 (Fig. 1-3).

The consistency index (K) was greatest for Agharan contains starch 0.1%, gum arabic 0.05% and whey 0.1% and calculated 4.0548 ,3.83 and 3.6845, respectively and

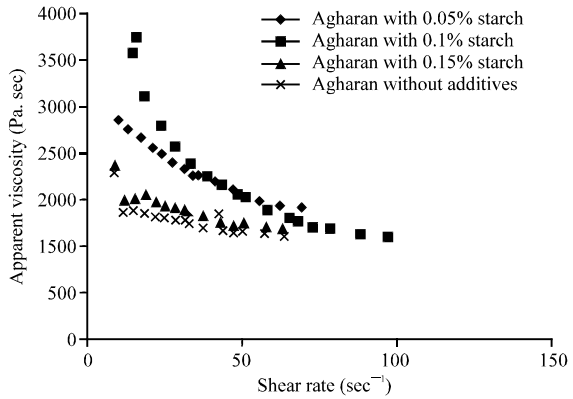

Fig. 3: Apparent viscosity versus shrear rate for Agharan contains different concentration of starch

for Agharan without additives was 3.0633. The flow behavior index was highest for Agharan contains 0.15% whey, 0.1% gum arabic and 0.15% starch and calculated 0.812, 0.4851 and 0.7952, respectively in comparison to Agharan without additives (0.7961). All samples showed rather similar flow curves except Agharan contains 0.15% whey powder that had sharp slope. In general, all samples showed the decrease in apparent viscosity with increasing the shear rate and in all concentration of Agharan contains gum arabic, apparent viscosity decreased slightly in comparrison to control and has mild slope (Fig. 1-3).

Effect of concentration on viscosity: Figure 4-6 show the influence of concentration on shear stress versus shear rate at constant temperature. The apparent viscosity analysis of the samples revealed a significant decrease in apparent viscosity values for samples containing 0.05% whey powder but a higher value seen in higher concentration of whey powder. The results suggested that rheological parameter values in the Agharan contains whey powder depended on whey concentration when present at low concentration because the whey proteins were not able to gel (Glibowski *et al*., 2006).

In all samples with increasing shear rate, decreased the shear stress. The slope of decrease in Agharan contains 0.15% whey powder is slight greater and in Agharan without additives is near to newtonian fluids. Agharan contains 0.15% starch is slight same to Agharan without additives. Saeple contains 0.1% starch in comparison to 0.05% had milder slope. In between all samples, Agharan with 0.05% whey powder in compared to others had lower shear stress with increase the shear rate.

The highest viscosity values were recorded for Agharan contains 0.1, 0.05% starch were 3520.7, 2678.4 and lowest for Agharan contains 0.15% gum arabic (823.25). Representative plots for shear stress versus shear rate is shown in Fig 4-6.

Whey proteins at low concentration do not influence significantly on rheological properties and at high starch concentrations, it was possible to produce a hard firm structure. The presence of gum arabic, starch especially whey powder at low concentrations led to weaker structure. Similar effects of starch addition on the properties of stirred yoghurts have been reported by (Williams *et al*., 2003). Also in the earlier study, Glibowski *et al*. (2006) noticed a similar tendency.

Effect of n on viscosity values: Agharan had shear thining behaviour and as expected in all samples apparent viscosity decreased gradually with increase in RPM, probably due to the disruption of the Agharan structure. Figure 7-9 show the influence of RPM on apparent viscosity of Agharan.

As showned in Fig. 7-9, addition of whey powder, starch and gum arabic to the Agharan resulted in a depression of apparent viscosity. All samples showed shear thining behavior as apparent viscosity decreased gradually when samples were subjected to shear rate. The apparent viscosity showed a decrease with increasing shear rate at all concentration ranges.

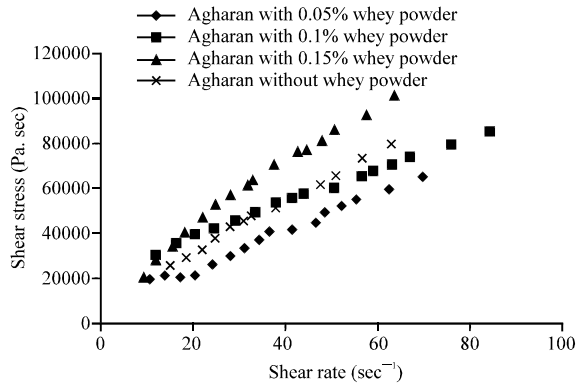

Fig. 4: Shear stress versus shear rate for Agharan contains different concentration of whey powder

The effect of the gelation process on the rheological properties of yogurt prepared from sheep, goat, cow and camel milks was investigated by Jumah *et al*. (2001). They found that the highest value for viscosity was earned by sheep milk, followed by goat, cow and camel milks. About 3 different transient viscosity stages were identified for cow, sheep and goat milk whereas camel milk showed no significant variation in viscosity during gelation.

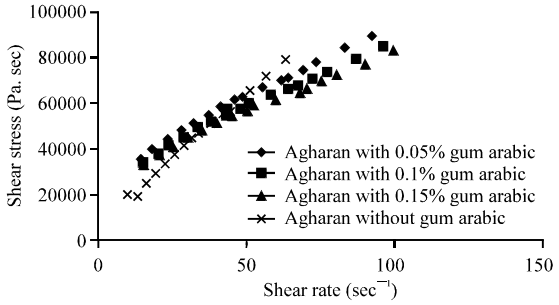

Fig. 5: Shear stress versus shear rate for Agharan contains different concentration of gum arabic

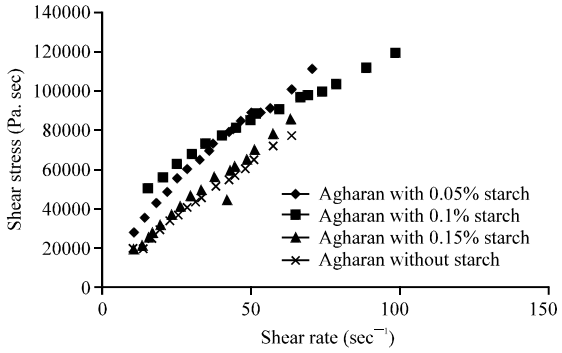

Fig. 6: Shear stress versus shear rate for Agharan contains different concentration of starch

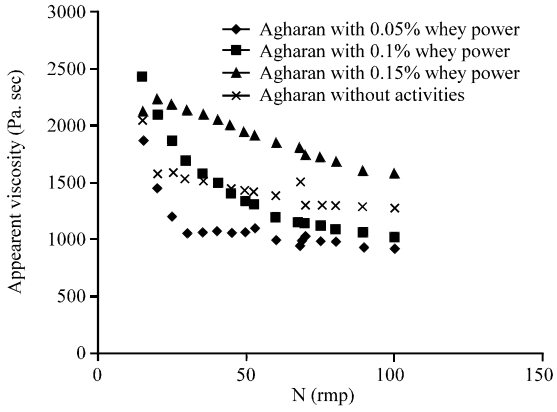

Fig. 7: Apparent viscosity versus N for different concentration of Aaghran contains whey powder

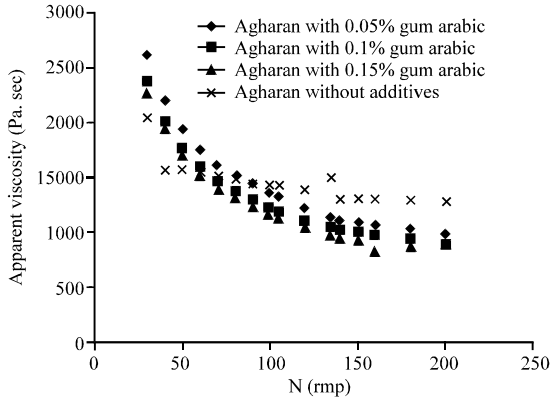

Fig. 8: Apparent viscosity versus N for different concentration of Agharan contains gum arabic

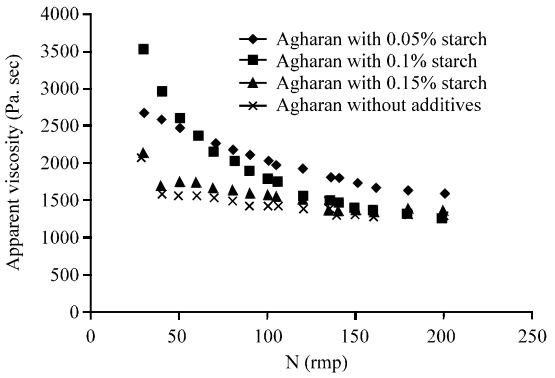

Fig. 9: Apparent viscosity versus N for different concentration of Agharan contains starch

After the aggregation/gelation of the whey proteins, rearrangements of the gel network are observed (Lucey *et al*., 1997, 1998) and may be due to aggregation of casein particles at iso-electric pH (4.6). Such rearrangements lead to a transition from an initial denatured whey protein induced gel formed at a high pH (5.2) to a network dominated by casein-casein interaction at a lower pH (4.6) (Lucey and Singh, 1998).

Adding 6% whey protein is sufficient to form stable 3 dimensional structure and reveals higher rheological parameters values. It can be due to change in the flow characteristic in the samples that arose from structural formation while in lower whey protein concentrations, the addition of whey powder produced a marginal decrease in viscosity of system typical for shear thining behavior (Alizadehfard and Wiley, 1996).

The concentration dependence of the apparent viscosity on shear rate, described by other researchers for whey protein, starch and gum arabic systems was confirmed by this study also for undenatured whey proteins (Williams *et al*., 2003; Glibowski *et al*., 2006; Alizadehfard and Wiley, 1996). The Mitschka method produces very useful information for quality control a variety of shear-thinning fluid foods.

CONCLUSION

The present research has shown that addition starch, whey powder and gum arabic decrease the apparent viscosity. The level of decrease was dependent on the level of adding. The amount of whey powder, starch and gum arabic affected the rheological and textural attributes of the Agharan. Accordingly, use of whey powder, starch and gum arabic in the manufacture of Agharan can improve its physical properties and prevent from syneresis.

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