

Rheological Behavior of *Agharan* Contains Different Concentrations of Whey Powder, Starch and Gum Arabic

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Abstract

The *Agharan* is fermented concentrated fermented camel milk which prepared in some pastoral region of Golestan Province in Iran, and among the Turkmen tribes where camels are kept and bred called *Agharan*. *Agharan* has not been introduced in any article, conferences or etc. in the world, yet. So this is the first article written about *Agharan* and has introduced it, and investigate the rheology of this product. Accordingly, this study can provide important information for other researchers. The aim of this work is to study the effect of 0.05, 0.1 and 0.15% Whey Powder, Gum Arabic and Starch at 30, 40, 50, 60, 70, 80, 90, 100, 105, 120, 135, 140, 150, 160, 180, 200 rpm on rheological properties of *Agharan* at 24°C. Results with Mitschka Method revealed all samples were Shear Thinning. All samples showed similar decrease in apparent viscosity with increasing the Shear rate. In all concentration of *Agharan* contain Gum arabic, viscosity decreased slightly in comparison to control. In contrast, *Agharan* contains 0.15% Whey powder has sharp slope. The level of decrease depended on the levels of materials added. The highest and lowest Apparent viscosity were recorded for *Agharan* contain 0.1, 0.05% Starch (3520.7, 2678.4) and 0.15% gum arabic (823.25) respectively. Accordingly Starch, Whey powder and Gum Arabic can alter rheological properties of *Agharan*.

Keywords: *Agharan*; Fermented camel milk; Starch; Rheological behavior; Shear thinning

Introduction

Rheology is the study of deformation and flow of fluids in response to stress. To make an incompressible fluid flow, a shear stress must be applied.

Camel is a useful animal which many years ago domesticated by human and used its Milk, Meat, Skin, Wool and so on. Fermented camel milk is one of the 3500 traditional fermented food exist in the world [1], 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 [2,3].

Camel milk and fermented camel milks are nutritious foods because has medicinal properties and in many region used against some diseases [4-7]. The *Agharan* is fermented concentrated camel milk which prepared in some pastoral region of Golestan Province in Iran, and among the Turkmen tribes where camels are kept and bred, 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. It is similar to concentrated yoghurt.

Most of whey protein is lost in the drainage without any benefit [8]. The environmental pollution and high cost of disposing it, also, the high nutritional value [9], and low cost of whey encouraged scientists to utilize it as an excellent food component in the foods [10]. Functional properties of whey proteins, such as emulsifying, water/fat holding, extending shelf-life, foaming, thickening and gelling properties [11], also nutritional value [12], make them interesting to be used as a food ingredient in conjunction fermented milks [13]. 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 [14]. Gum Arabic, also called Acacia Gum is the natural exudate from the *Acacia Senegal*, which have high molecular weight consisting of branched arabinogalactan heteropolymers [15,16]. The gums have the

ability to control the rheology and texture throughout the stabilization of emulsions, suspensions, foams and starch gelatinization [17]. Gum Arabic also contains proteins (2%). Uronic acid in Gum Arabic is responsible for the polyanionic character of it with a pH around 3 [18,19].

Starch is one of the most used thickeners in dairy products due to improve mouth feel, prevent syneresis and low cost when compared with other hydrocolloids [20].

The aim of the present work is to study the effect of the addition of different concentration of Whey Powder, Gum Arabic and Starch on rheological properties of *Agharan*.

Material and Methods

Materials

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 laboratory of Department of Food Science and Technology of Agricultural Science and Natural Resources University, Gorgan, Iran.

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Preparation method of *Agharan*

For preparation of *Agharan* allow to camel milk to quiet in a steady place at ambient temperature after it break into two 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

Three 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 9.51 to 100 s⁻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 three 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.

Mitschka method [21] 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 τ_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 one, 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 γ_i (in s⁻¹) are then calculated as

$$\gamma_i = k_{ny} (n) N_i$$

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

Spindle number	1	2	3	4	5	6	7	
k _{at}	0.035	0.119	0.279	0.539	1.05	2.35	8.4	
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	0.449	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	

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

<i>Agharan</i> without additives		
Shear stress (pa)	Shear rate (s ⁻¹)	Apparent viscosity(pa. s)
19530	9.51	2053.6
19920.6	12.68	1571
24998.4	15.85	1577.2
29490.3	19.02	1550.5
33786.9	22.19	1522.6
37888.2	25.36	1494
41989.5	28.53	1441.7
45700.2	31.7	1441.64
47457.9	33.285	1425.8
52535.7	38.04	1381
57222.9	42.795	1505.8
57808.8	44.38	1302.59
61910.1	47.55	1302
66206.7	50.72	1305.33
73432.8	57.06	1286.94
80463.6	63.4	1269.14

Pa=pascal, pa.s=pascal second

Table 2: *Agharan* without additives.

Agharan contains 0.05% Starch			Agharan contains 0.1% Starch			Agharan contains 0.15% Starch		
Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)
28123.2	10.5	2678.4	51754.5	14.7	3520.7	20311.2	9.51	2135.77
36130.5	14	2580.75	58394.7	19.6	2979.3	21873.6	12.68	1725
43161.3	17.5	2466.36	64058.4	24.5	2614.62	27732.6	15.85	1749.7
49410.9	21	2352.9	69331.5	29.4	2358.2	32810.4	19.02	1762.8
55269.9	24.5	2255.9	74018.7	34.3	2157.98	37497.6	22.19	1689.84
60738.3	28	2169.22	78510.6	39.2	2002.82	41989.5	25.36	1655.74
66011.4	31.5	2095.6	83197.8	44.1	1886.57	46286.1	28.53	1622.36
71089.2	35	2031.12	87299.1	49	1781.6	50387.4	31.7	1589.5
73432.8	36.75	1998.17	89838	51.45	1746.12	52340.4	33.285	1572.49
80268.3	42	1911.15	92767.5	58.8	1577.68	58004.1	38.04	1524.8
86322.6	47.25	1826.93	98821.8	66.15	1493.9	60543	42.795	1414.72
88080.3	49	1797.56	99993.6	68.6	1457.6	63081.9	44.38	1421.4
90814.5	52.5	1729.8	102141.9	73.5	1389.68	66402	47.55	1396.46
93744	56	1674	105657.3	78.4	1347.67	71870.4	50.72	1417
103313.7	63	1639.9	115227	88.2	1306.42	79682.4	57.06	1396.47
112492.8	70	1607	123234.3	98	1257.49	87103.8	63.4	1373.88

Ss=shear stress, Sr=shear rate, A. vis=Apparent viscosity, Pa=pascal, pa.s=pascal. second

Table 3: Agharan with different concentration of Starch.

Agharan contains 0.05% Gum arabic			Agharan contains 0.1% Gum arabic			Agharan contains 0.15% Gum arabic		
Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)
36130.5	13.8	2618.15	34177.5	14.4	2373.43	34177.5	15	2278.5
40622.4	18.4	2207.74	38474.1	19.2	2003.86	38474.1	20	1923.7
44723.7	23	1944.5	42380.1	24	1765.84	42380.1	25	1695.2
48434.4	27.6	1754.87	45895.5	28.8	1593.6	46090.8	30	1536.36
52145.1	32.2	1619.4	49410.9	33.6	1470.56	49215.6	35	1406.16
55660.5	36.8	1512.51	52926.3	38.4	1378.29	52731	40	1318.27
59175.9	41.4	1429.37	56051.1	43.2	1297.47	55660.5	45	1236.9
62300.7	46	1354.36	58980.6	48	1228.76	58394.7	50	1167.9
63667.8	48.3	1318.17	60347.7	50.4	1197.37	59761.8	52.5	1138.32
68159.7	55.2	1234.77	64449	57.6	1118.9	63277.2	60	1054.62
71479.8	62.1	1151	67769.1	64.8	1045.82	66402	67.5	983.73
72261	64.4	1122	68745.6	67.2	1023	67378.5	70	962.55
76167	69	1103.87	72261	72	1003.62	71089.2	75	947.85
79096.5	73.6	1074.68	75190.5	76.8	979	74018.7	80	825.23
85346.1	82.8	1030.75	80854.2	86.4	935.81	79487.1	90	883.19
91205.1	92	991.36	86517.9	96	901.228	84955.5	100	895.55

Ss=shear stress, Sr=shear rate, A. vis=Apparent viscosity, Pa=pascal, pa.s=pascal. Second

Table 4: Agharan with different concentration of Gum Arabic.

Statistical analysis

The effects of concentration, N, and Shear rate on the Apparent viscosity were studied. Related graphs and curves drawn by Excel. A significance level of 0.05 was utilized for all analyses.

Results and Discussion

Viscosity measurements

After calculating the Shear rate, Shear stress and Apparent viscosity (Tables 2-5), established the related curves. The Apparent viscosity of *Agharan* samples decreased with increase shear rate, indicating a non-Newtonian fluid and showed shear-thinning behavior (Figures 1-3) that characterized by flow behavior index values of less than 1.

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 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* contain Gum Arabic, apparent viscosity decreased slightly in comparison to control and has mild slope (Figures 1-3).

Effect of concentration on viscosity

Figures 4, 5 and 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 [22].

In all samples with increasing Shear rate, decreased the Shear

Agharan contains 0.05% whey powder			Agharan contains 0.1% whey powder			Agharan contains 0.15% whey powder		
Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A.vis (pa.s)	Ss (pa)	Sr (s ⁻¹)	A. vis (pa.s)
19725.3	10.5	1878.6	30662.1	12.6	2433.5	20311.2	9.51	2135.77
20506.5	14	1464.75	35154	16.8	2092.5	28513.8	12.68	2248.72
21092.4	17.5	1205.28	39255.3	21	1869.3	34958.7	15.85	2205.6
22068.9	21	1050.9	42770.7	25.2	1697.25	40817.7	19.02	2146
26170.2	24.5	1068.17	46286.1	29.4	1574.35	47067.3	22.19	2121.1
30076.2	28	1074.15	49801.5	33.6	1482.18	52340.4	25.36	2063.9
33591.6	31.5	1066.4	52926.3	37.8	1400.16	57222.9	28.53	2005.7
37107	35	1060.2	55855.8	42	1329.9	62105.4	31.7	1959.16
40427.1	36.75	1100	57222.9	44.1	1297.57	64253.7	33.285	1930.41
41598.9	42	990.45	60738.3	50.4	1205.125	71089.2	38.04	1868.8
45114.3	47.25	954.8	65620.8	56.7	1157.33	76948.2	42.795	1798.85
49996.8	49	1020.34	67378.5	58.8	1145.9	78510.6	44.38	1769
52145.1	52.5	993.24	70503.3	63	1119.1	82221.3	47.55	1729.15
55465.2	56	990.45	73432.8	67.2	1092.75	85541.4	50.72	1686.54
58590	63	930	79487.1	75.6	1051.41	91986.3	57.06	1612.1
64839.6	70	926.28	85736.7	84	1020.67	101556	63.4	1601.83

Ss=shear stress, Sr=shear rate, A. vis=Apparent viscosity, Pa=pascal, pa.s=pascal. Second

Table 5: *Agharan* with different concentration of Whey powder.

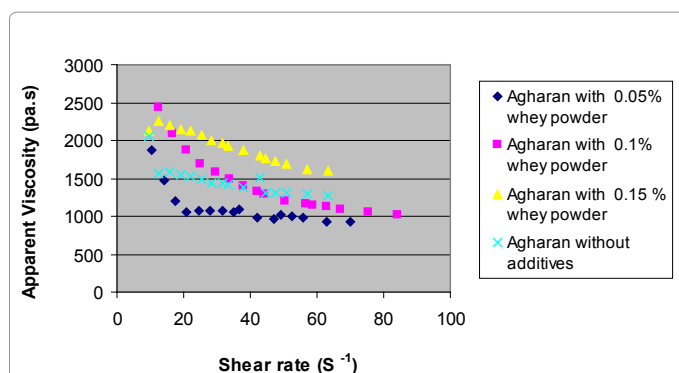


Figure 1: Apparent viscosity versus Shear rate for *Agharan* contains different concentration of Whey powder.

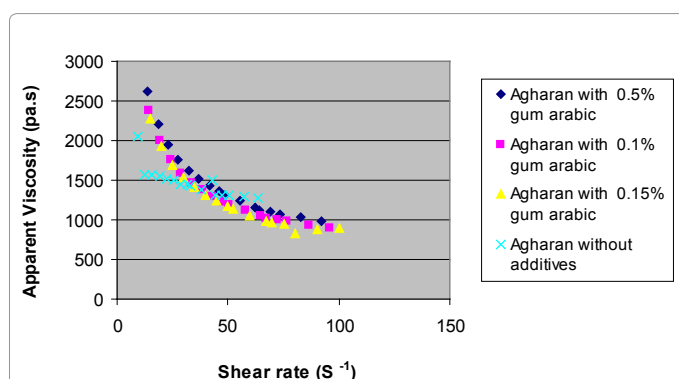


Figure 2: Apparent viscosity versus Shear rate for *Agharan* contains different concentration of Gum Arabic.

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. Sample 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 Figures 4, 5 and 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 [23]. Also In the previous study noticed a similar tendency [22].

Effect of non-viscosity values

Agharan had Shear thinning behavior and as expected in all samples apparent viscosity decreased gradually with increase in RPM, probably due to the disruption of the *Agharan* structure. Figures 7, 8 and 9 show the influence of RPM on Apparent viscosity of *Agharan*. As showed in figures, addition of whey powder, starch and Gum arabic to the *Agharan* resulted in a depression of apparent viscosity. All samples showed Shear thinning 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. 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. [24]. They found that the highest value for viscosity was earned by sheep milk, followed by goat, cow and camel milks. Three different transient viscosity stages were identified for cow, sheep and goat milk, whereas camel milk showed no significant variation in viscosity during gelation. The ratio of casein and whey protein in cow, sheep and goat milks are almost 80: 20, and for camel milk is about 70: 30, this ratio seems have effect on viscosity and rheology properties of products made from cow, sheep, goat and camel milks. And differences in viscosity and rheology properties of these products can be attributed to the different nature of these milks.

After the aggregation/gelation of the whey proteins, rearrangements of the gel network are observed [25,26], and may be due to aggregation of casein particles at iso-electric pH (pH 4.6). Such rearrangements lead to a transition from an initial denatured whey protein (associated with

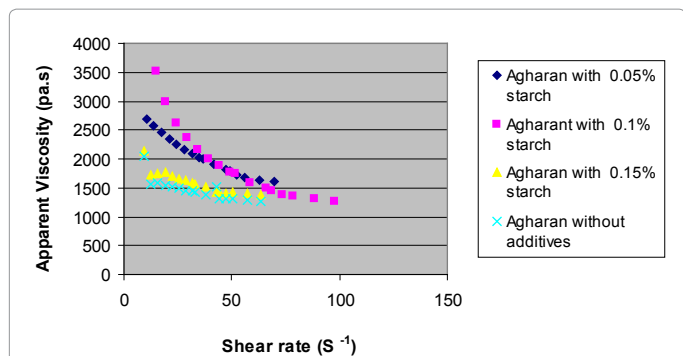


Figure 3: Apparent viscosity versus Shear rate for Agharan contains different concentration of Starch.

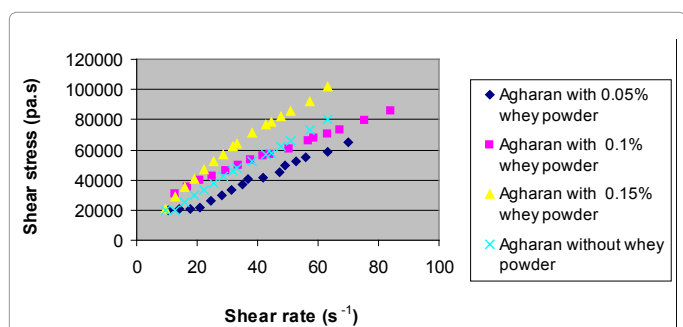


Figure 4: Shear stress versus Shear rate for Agharan contains different concentration of Whey powder.

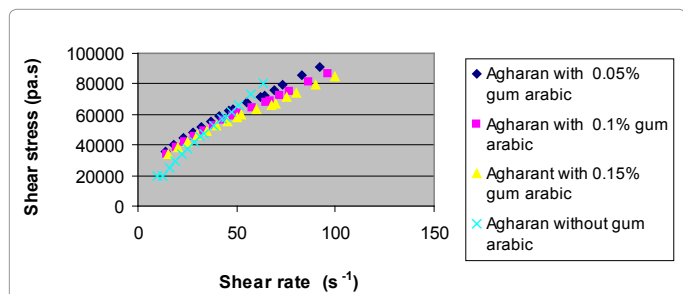


Figure 5: Shear stress versus Shear rate for Agharan contains different concentration of Gum Arabic.

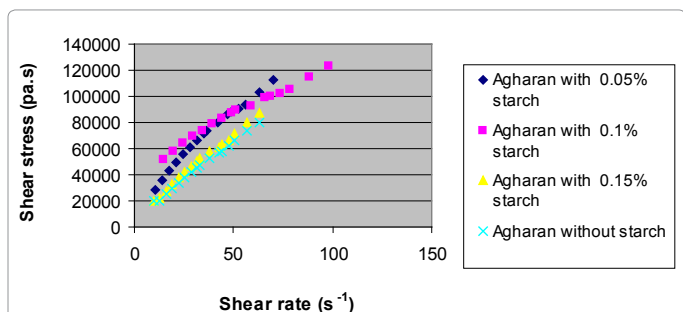


Figure 6: Shear stress versus Shear rate for Agharan contains different concentration of Starch.

Adding 6% whey protein is sufficient to form stable three dimensional structures 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 thinning behavior, without contributing to the formation of intermolecular bonds [28].

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 [23,22,28].

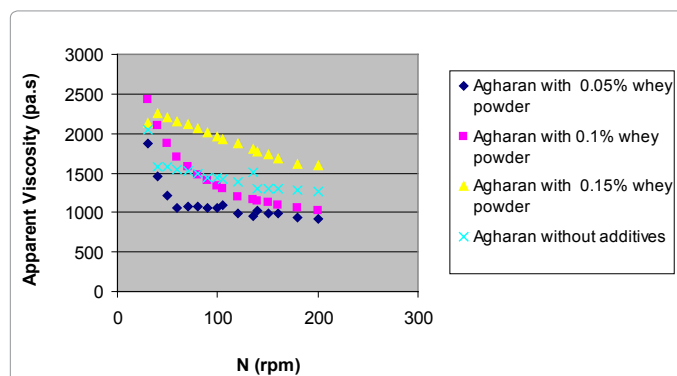


Figure 7: Apparent viscosity versus N for different concentration of Agharan contains Whey powder.

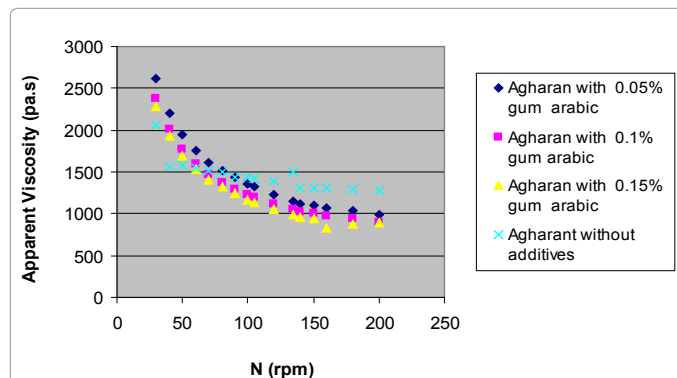


Figure 8: Apparent viscosity versus N for different concentration of Agharan contains Gum Arabic.

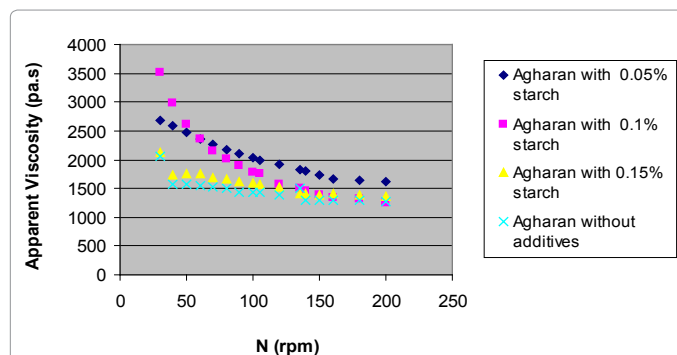


Figure 9: Apparent viscosity versus N for different concentration of Agharan contains Starch.

casein micelles) induced gel formed at a high pH (pH 5.2) to a network dominated by casein–casein interaction at a lower pH (pH 4.6) [27].

Near neutral pH, whey proteins gels can be formed either by heat-induced gelation in which it is necessary to heat whey proteins in the presence of ions, or by cold- or ion-induced gelation in which the whey proteins form a three-dimensional network by aggregation. In the latter case, it is prerequisite to unfold the whey protein monomers by prior heating to expose sulfhydryl and hydrophobic amino acid residues that are buried in the interior of the globules. The unfolded proteins form polymers mainly via sulfhydryl/disulfide interactions and also via hydrophobic interactions [29]. Same reasons exist for formation of firm structure by starch and Gum arabic but with slight different in regard with they are hydrocolloids. Same results approached in this study and these hydrocolloids and whey powder decreased the apparent viscosity.

A rapid breakdown of the structure occurs on initial shearing followed by much slower changes at higher shear rates. This behavior can be attributed to combined effects of breakdown of weak linkages between the proteins and/or between the proteins and stabilizer, and of reformation of such linkages as a result of Brownian motion and molecular collisions [30].

Conclusions

The Mitschka method produces very useful information for quality control a variety of shear-thinning fluid foods. The present work 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*. All *Agharan* samples in this study were Shear Thinning. Accordingly, we concluded that use of Whey powder, Starch and Gum arabic in the manufacture of *Agharan* can improve its physical properties.

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