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PHYSICAL PROPERTIES OF DIFFERENT ADULTERATED EGYPTIAN HONEY

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Abstract-The physical properties (pH, electrical conductivity, density, total suspended solids, refractive index, surface tension and moisture content) of different types of Egyptian honeys (black seed honey, clover honey, desert honey and mountain flower honey) were investigated. Honey samples each of volume 100ml. were adulterated with different volumes (2, 4, 6, 8 and 10 ml) of starch solution, glucose, molasses and distilled water respectively and were tested and compared to the pure sample. Rheological properties of pure Egyptian honey samples were compared to purchased and adulterated samples, the flow behavior index indicates that the samples exhibit shear thinning flow behavior and some were approximately Newtonian behavior. Apparent viscosity and shear stress of pure and purchased samples of all honey types studied were higher than the adulterated samples; the effect of adding different volumes of adulterants was also studied at different shear rates 1.1308, 5.6544, 11.3088 s-1, which revealed that apparent viscosity decreases as volume of adulterants increase for all the studied shear rates. The combined effect of shear rate and volume of adulterant on the shear stress was determined with data analysis.

Keywords: Honey, physical properties, Rheology, surface tension and Adulteration

1. INTRODUCTION

Honey is a natural viscous aromatic fluid produced by honey bees using flowers nectar. By regurgitation and evaporation bees convert flowers nectar to honey; it is then stored as primary food source in wax honeycombs inside the beehive. Honey's sweetness -which is very similar to that of sugar- is mainly due to the presence of fructose and glucose.

Flow properties for food are quite different and a bit complicated than any simple fluid; it is also dependent upon the way it was previously processed. For instance yoghurt contains bonded molecular chains of proteins, if these bonded chains were pumped or stirred the flow properties of yoghurt changes. It can also be observed when comparing a stirred and sit yoghurt the both are made of the same ingredients however; the first has liquid like properties whilst the second behaves as a solid. For a proper design of any operation unit as well as the transport process in the operation, it is essential to study carefully the rheological properties of the fluid. [1]

Rheology is the study of flow of a fluid or a suspension, the relation between shear rate -or rate of deformation- and the corresponding shear stress is referred to as rheological behavior of a fluid. The formulation of mathematical relationships and the measurement of the deformation of a fluid with stress are two main targets in rheology; for they are used to create models and equations to compute velocity profiles and volumetric flow rates at a given flow situation [2] . Honey mainly is a Newtonian fluid, as determined by many studies all over the world (El-Bialee and Sorour 2011, Lazaridou et al., 2004, Yoo 2004, Juszczak and Fortuna 2006, Sabato 2004, Bhandari et al., 1999 and Mossel et al., 2000). Some honey types in certain places exhibited shear thinning behavior as determined by (G´omez-D´ıaz, 2005 and De M. Queiroz, 2005) other types of honey showed Herschel-Bulkley behavior as reported by (Ahmed et al., 2007).

El-Bialee and Sorour (2011) studied the effect of different adulterants on Egyptian honey properties. Clover honey samples were adulterated by four materials respectively; the adulterants were distilled water, glucose, molasses and starch. Different concentrations of these adulterants were used 1, 3, 6, 12, and 24%. Rheological and physicochemical properties of pure and adulterated honey samples were compared, the samples were found to differ from one another in refractive index, total soluble solids (T.T.S), moisture content, density, specific weight, PH, surface tension and capillary action.

The objective of this research is to determine the physical properties and flow behavior of adulterated honey samples and compare them to pure samples.

2. MATERIAL AND METHODS

2.1 Material

Honey was collected from the Ministry of Agricultural outlet El-Dokki, Giza governorate between November 2015 and April 2016. Black Seed Honey, Clover Honey, Desert Honey and Mountain Flowers Honey were selected. The

same honey types selected from the outlet were purchased from the local market for comparison -except Desert Honey due to unavailability-. Distilled Water, Glucose, Molasses and Starch Solution were used as adulterants.

2.2 Methods

2.2.1 Preparation of Honey Samples

Starch solution (4%) was prepared by adding 4 gram (wt. %) of starch to 100 ml distilled water; the solution was then stirred and gelatinized in microwave so that the starch is completely suspended -gelatinized- in water. [3]
Pure honey was divided into equal volume of 100 ml; each adulterant was added to the different types of honey with different volumes (2, 4, 6, 8 and 10 ml) separately. The physical properties of samples were then determined in comparison to pure sample. A volume of 100ml was also taken of the honey purchased from local market from all types of honey.

2.2.2 Measuring of Physical Properties

Density of pure, purchased and adulterated honey samples were determined as mass per unit volume in g/cm3 at room temperature. The refractive index, total suspended solids (T.S.S.) and moisture content were determined by Abbe 60 digital refractometer (Bellingham and Stanly Limited); the refractmeter was first calibrated with distilled water before measuring any of the samples. A digital pH meter (Lovibond Water Testing- Tintometer Group) was used to determine the PH and electrical conductivity in Siemens (kg -1.m-2.s3.A2) of samples at room temperature. The electrical conductivity depends upon the mineral content, proteins, organic acids and some sugars; it can be used as an additional method to determine the botanical source of the honey. [13, 14]
Capillary Tubes were used to determine the height that honey would ascend; surface tension can be calculated by the following equation: [15]

$$\sigma = \frac{\rho g h r}{2} \qquad 2.1$$

Where: σ = the surface tension in dyne.cm-1.
ρ = the density of fluid in g.cm-3.
g = the acceleration due to gravity in cm.s-2.
h = height of fluid in capillary tube in cm.
r = radius of capillary tube in cm.

Rheological properties of honey samples were measured using Brookfield digital rheometer (DVIII Ultra) spindle HA-07. Apparent viscosity was directly obtained from the rheometer whilst shear rate and shear stress were calculated. Shear rate was calculated using the following equation: [16]

$$\gamma = \frac{2\pi R_c^2}{60(R_c^2 - R_b^2)} * rpm \qquad 2.2$$

Where: γ = the shear rate in s-1.
Rc = the radius of container cm.
Rb = the radius of spindle cm.
rpm = the revolutions per minute of the spindle .

3. RESULTS AND DISCUSSIONS

3.1 Physical Properties of Pure, Purchased and Adulterated Honey

Physical properties of honey were analyzed to formulate ranges of various honey constituents and characteristics. Honeys industries have shown great interest in these constituents as they influence the storage quality, granulation, texture, flavor, nutritional and medicinal values of honey. Honey is generally evaluated by a physicochemical analysis of its constituents, determining the characteristics of honey allow packaging and storage to be in the appropriate conditions such that the qualities and savor of honey are preserved. [17]
Black seed honey had the values of pH for adulterated samples indicated a slight variation from the pure sample in the range of 19.5 - 20.4% decrease, electrical conductivity of samples of adulterated black seed varied in a wide range of 33.33% lower than the value of pure sample to 45.9% more than the electrical conductivity of pure sample. Density of samples adulterated with glucose, molasses and distilled water decreased by 3.1 - 9.3% from the pure sample, the density increased however with the addition of starch solution in the range of 1 - 10.85%, adulterating honey with glucose and molasses has a slight effect on the value of total suspended solids whilst adulterating black seed honey with starch solution and distilled water resulted in reduction in the range of 1.85 - 9.25%. Refractive index of black seed honey adulterated with glucose, molasses and distilled water were approximately similar to that of the pure sample, the addition of starch solution however, increased from the pure sample in the range of 0.46 - 1.2 %, samples adulterated with starch solution, molasses and distilled water had their surface tension values higher than

those of pure honey in the wide range of 44.5 -114.7%, while samples adulterated with glucose were around the pure sample with the range of 52.5% less than pure to 97.36% more than the pure black seed honey sample. Moisture content of black seed honey adulterated with glucose and molasses varied slightly from the moisture content value of pure black seed honey, adding starch solution or distilled water increased moisture content in the range of 7.89 - 39.47% as shown in table-3.1.

Table -3.1 Physical Properties of Black Seed Honey with Different Adulterants

	pH	Conductivity	Density	T.S.S.	Refractive Index	Height in Capillary Tube	Surface Tension	Moisture Content
		$kg^{-1}.m^{-2}.s^3.A^2$ (S)	g/cm^3	%		mm	$dyne.cm^{-1}$	%
Pure Honey	4.56	2.7	1.2936	81	1.493	10	0.729	19
Purchased Honey	3.56	0.2	1.3226	80.5	1.492	13	0.969	19.5
Starch Solution 4%	5.32	55.6	0.8229	3.5	1.3355	11	0.511	96.5
2 ml	3.64	2.3	1.365	78	1.486	17	1.309	22
4 ml	3.63	2.1	1.431	76.5	1.482	19	1.534	23.5
6 ml	3.65	1.8	1.303	76.5	1.481	19	1.397	23.5
8 ml	3.66	1.8	1.331	73.5	1.475	20	1.502	26.5
10 ml	3.67	2.5	1.388	74.5	1.477	20	1.566	25.5
Glucose	5.39	0.2	1.19	68.5	1.508	3	0.2013	31.5
2 ml	3.65	2.87	1.215	81.5	1.492	21	1.44	18.5
4 ml	3.59	3.48	1.221	81	1.492	16	1.102	19
6 ml	3.57	3.2	1.207	81	1.4915	7.5	0.511	19
8 ml	3.55	3.01	1.25	81.5	1.4925	5	0.352	18.5
10 ml	3.52	3.09	1.227	81	1.4915	5	0.346	19
Molasses	4.67	327	1.23	73.2	1.4739	27.94	1.938	26.8
2 ml	4.02	3.69	1.206	81.5	1.494	15.5	1.054	18.5
4 ml	4.06	3.62	1.231	81	1.493	16.5	1.145	19
6 ml	4.11	3.59	1.226	80	1.491	17	1.176	20
8 ml	4.2	2.96	1.231	80.5	1.492	16	1.111	19.5
10 ml	4.21	2.55	1.218	80.5	1.492	15.5	1.065	19.5
Distilled Water	7	6.35	1	-	1.335	36.38	2.052	-
2 ml	3.84	3.94	1.246	79.5	1.489	19	1.335	20.5
4 ml	3.75	3.35	1.2028	77	1.483	19.5	1.323	23
6 ml	3.8	3.17	1.187	75	1.477	20	1.341	25
8 ml	3.85	2.92	1.194	76.5	1.482	20	1.347	23.5
10 ml	3.79	2.89	1.172	75.5	1.478	21.5	1.421	24.5

The pH values for clover honey samples were all of acidic nature, pH values of adulterated samples were around the pure sample by about 10.1 % less than the pure and 20.16% more than the pure sample, the samples adulterated with 4% starch solution, glucose, molasses and distilled water had lower values of electrical conductivity than the pure clover sample. The density of pure honey was higher than that of adulterated samples and was in the range of 5.03 - 18.6%, total suspended solids values for samples adulterated with starch solution and distilled water were lower than the pure sample in the range of 1.25 - 6.9%, while the values of total suspended solids for samples adulterated with glucose and molasses were higher than that of pure sample and was in the narrow range of 1.88 - 3.14%.

The results verified that refractive index of clover honey adulterated with glucose and molasses were approximately similar to that of the pure sample, adding starch solution or distilled water reduced the values of refractive index in the range of 0.06 - 1%, all the adulterated samples had their surface tension values higher than those of pure clover honey and was in the wide range of 26.43 - 274.17%. Values of moisture content increased with the addition of 4% starch solution and distilled water compared to pure honey sample, the increase was in the range of 4.87 - 26.8%, while adding glucose to pure clover honey reduced the values of moisture content by 9.75 - 12.19%, adding molasses to pure clover honey slightly affected the moisture content as shown in table-3.2.

Table-3.2 Physical Properties of Clover Honey with Different Adulterants

	PH	Conductivity	Density	T.S.S.	Refractive Index	Height in Capillary Tube	Surface Tension	Moisture Content
		$kg^{-1}.m^{-2}.s^{3}.A^{2}$ (S)	g/cm^{3}	%		mm	$dyne.cm^{-1}$	%
Pure Honey	3.67	4.55	1.45	79.5	1.49	6	0.49074525	20.5
Honey around Honey comb	3.8	4.6	1.38	81	1.493	8	0.6228	19
Purchased Honey	3.3	4.26	1.41	80	1.491	9	0.715	20
Starch Solution 4%	5.32	55.6	0.8227	3.5	1.3355	11	0.5106	96.5
2 ml	3.3	3.83	1.3529	78.5	1.487	9	0.6868	21.5
4 ml	3.49	4.24	1.375	78	1.486	8	0.6204	22
6 ml	3.44	3.72	1.377	76.5	1.482	19	1.47617	23.5
8 ml	3.41	4.33	1.3611	76.5	1.482	21	1.6123	23.5
10 ml	3.33	4.23	1.345	75	1.477	24	1.8214	25
Glucose	5.39	0.2	1.19	68.5	1.508	3	0.2013	31.5
2 ml	4.41	2.92	1.2156	81.5	1.494	20	1.3714	18.5
4 ml	4.05	2.95	1.2115	81.5	1.495	13	0.8884	18.5
6 ml	3.88	3.04	1.2264	81.5	1.495	12	0.8301	18.5
8 ml	3.61	2.99	1.2222	82	1.496	13.5	0.9307	18
10 ml	3.62	2.96	1.2364	81.5	1.495	12.5	0.8717	18.5
Molasses	4.67	327	1.23	73.2	1.4739	27.94	1.938	26.8
2 ml	3.82	3.22	1.2254	81	1.493	17	1.175	19
4 ml	3.79	3.27	1.2115	80	1.49	20	1.366	20
6 ml	3.9	2.75	1.2547	80	1.491	19.5	1.3801	20
8 ml	4.11	2.83	1.2407	78.5	1.486	21.5	1.5047	21.5
10 ml	4.13	3.82	1.209	78	1.486	25	1.705	22
Distilled Water	7	6.35	1	-	1.335	36.38	2.052	-
2 ml	3.56	2.74	1.2424	79.5	1.489	17	1.191	20.5
4 ml	3.48	2.67	1.1986	78	1.485	19	1.2846	22
6 ml	3.46	2.59	1.1984	77	1.482	20.5	1.3858	23
8 ml	3.49	2.55	1.1797	75.5	1.479	21	1.3975	24.5
10 ml	3.49	2.51	1.1837	74	1.475	27.5	1.8361	26

Adulterated desert honey samples indicated a slight variation in pH values from that of pure sample, the percentage range of change was in the range of 6.2% less than the pure and 10.59% more than the pure sample, all the adulterated samples had lower values of electrical conductivity than the pure desert sample. The density of desert honey samples adulterated with molasses and distilled water were less than that of pure sample in the percentage range of 5.32 - 9.72 %, while the samples adulterated with starch solution and glucose had their density values more

than that of the pure sample in the range of 3.2 - 11.45%, samples adulterated with starch solution or distilled water had their total suspended solids values lower than that of the pure sample in the range of 1.25 - 9.37%, whilst samples adulterated with glucose had higher values than the pure sample in the narrow range of 0.625 - 2.5%, samples adulterated with molasses had nearly the same total suspended solids as the pure sample. The results verified that refractive index of desert honey adulterated with glucose and molasses were approximately similar to that of the pure sample; the addition of starch solution or distilled water however, were lower than that of the pure sample and was in the range of 0.2 - 1.34%. All the adulterated samples had their surface tension values lower than that of pure sample and were in the range of 46.4% less than the pure to 44% more than the pure sample. Values of moisture content of samples adulterated with starch solution or distilled water were more than that of pure sample and in the range of 5 - 37.5%, moisture content of desert honey adulterated with glucose had lower values than that of the pure sample; values were in the range of 2.5 - 12.5%, upon the addition of molasses moisture content value varied slightly from that of pure desert honey as shown in table- 3.3.

Table-3.3 Physical Properties of Desert Honey with Different Adulterants

	pH	Conductivity	Density	T.S.S.	Refractive Index	Height in Capillary Tube	Surface Tension	Moisture Content
		$kg^{-1}.m^{-2}.s^{3}.A^{2}$ (S)	g/cm^{3}	%		mm	$dyne.cm^{-1}$	%
Pure Honey	3.87	4.25	1.33	80	1.491	24	1.8005274	20
Starch Solution 4%	5.32	55.6	0.8229	3.5	1.3355	11	0.5106	96.5
2 ml	3.78	2.8	1.4823	75	1.488	31	2.592	25
4 ml	3.83	3.57	1.3865	73	1.473	33	2.5	27
6 ml	3.75	3.6	1.3726	75	1.478	14	1.0839	25
8 ml	3.87	3.62	1.3833	75	1.478	17	1.3265	25
10 ml	3.96	3.42	1.3701	75	1.478	17.5	1.35326	25
Glucose	5.39	0.2	1.19	68.5	1.508	3	0.2013	31.5
2 ml	3.63	3.26	1.4215	82	1.496	15	1.20285	18
4 ml	3.88	3.12	1.4134	81.5	1.495	16	1.27567	18.5
6 ml	3.75	3.17	1.395	80.5	1.493	14	1.10186	19.5
8 ml	3.72	3.14	1.4259	82.5	1.494	13	1.0456	17.5
10 ml	3.9	3.16	1.4236	82	1.493	12	0.9636	18
Molasses	4.67	327	1.23	73.2	1.4739	27.94	1.9385	26.8
2 ml	4.18	2.76	1.2156	80	1.491	20.5	1.4057	20
4 ml	4.23	2.88	1.2212	79.5	1.4895	16.5	1.13655	20.5
6 ml	4.28	3.2	1.2264	80.5	1.492	16	1.1068	19.5
8 ml	4.27	3.24	1.2592	80.5	1.492	19	1.3496	19.5
10 ml	4.28	3.26	1.227	80	1.491	18.5	1.2807	20
Distilled Water	7	6.35	1	-	1.335	36.38	2.0521	-
2 ml	3.97	2.85	1.2465	79	1.488	17	1.1953	21
4 ml	4.06	3.05	1.2018	75.5	1.48	16	1.08467	24.5
6 ml	4.04	3.13	1.2452	75	1.478	20	1.4047	25
8 ml	4.08	3.57	1.200	74.5	1.476	20.5	1.3883	25.5
10 ml	4.09	3.11	1.206	72.5	1.471	21.5	1.463	27.5

The pH values for mountain flower honey samples were all of acidic nature, adulterated samples had the pH values in the range of 10.1% less than the pure sample and 16.16% more than the pure sample, all the adulterated samples had lower values of electrical conductivity than the pure mountain flower sample. The density of pure honey was

higher than that of adulterated samples, it was in the range of 0.896 - 17.64%. Adulterating mountain flower honey with starch solution or distilled water resulted in values lower than that of pure sample, the results were in the range of 1.26 - 11.39%, the values of total suspended solids for samples adulterated with glucose and molasses were higher than that of pure sample and were in the range of 1.26 - 4.43%. The results verified that refractive index of mountain flower honey adulterated with molasses and distilled water were approximately similar to that of the pure sample; the addition of starch solution or glucose resulted in reducing refractive index in the case of starch solution 0.6 - 1.54% and increasing the refractive index in case of glucose 0.33 - 0.6%. Surface tension of adulterated mountain flower honey samples were in the range of 54% less than the pure sample and 35.3% more than the pure sample. Values of moisture content increased with the addition of starch solution or distilled water and were in the range of 4.76 - 42.85%, moisture content of mountain flower honey adulterated with glucose or molasses had lower values than that of pure sample and were in the range of 2.38 - 16.66% as shown in table -3.4

Table-3.4 Physical Properties of Mountain Flower Honey with Different Adulterants

	pH	Conductivity	Density	T.S.S.	Refractive Index	Height in Capillary Tube	Surface Tension	Moisture Content
		$kg^{-1}.m^{-2}.s^{3}.A^{2}$ (S)	g/cm^{3}	%		mm	$dyne.cm^{-1}$	%
Pure Honey	3.96	4.71	1.45	79	1.488	21	1.717	21
Purchased Honey	3.83	4.81	1.41	81.5	1.494	8	0.636	18.5
Starch Solution 4%	5.32	55.6	0.8229	3.5	1.3355	11	0.5106	96.5
2 ml	4.25	5.5	1.3872	75.5	1.479	21	1.64328	24.5
4 ml	4.08	5.11	1.317	74.5	1.477	22	1.6347	25.5
6 ml	4.03	5.86	1.33	75	1.472	22	1.653	25
8 ml	4	4.9	1.383	72.5	1.472	24	1.8727	27.5
10 ml	3.98	4.66	1.3227	70	1.465	25	1.8653	30
Glucose	5.39	0.2	1.19	68.5	1.508	3	0.2014	31.5
2 ml	3.66	3.02	1.396	81	1.493	10	0.7874	19
4 ml	3.66	3.06	1.466	81.5	1.495	10	0.827	18.5
6 ml	3.65	2.95	1.419	82.5	1.497	11	0.881	17.5
8 ml	3.59	2.98	1.437	81.5	1.495	13	1.0537	18.5
10 ml	3.56	2.96	1.419	82	1.496	11.5	0.9205	18
Molasses	4.67	327	1.23	73.2	1.4739	27.94	1.9385	26.8
2 ml	4.47	3.62	1.255	79.5	1.4895	21	1.486	20.5
4 ml	4.3	3.44	1.221	80	1.4905	23	1.584	20
6 ml	4.2	3.24	1.424	82	1.496	20	1.607	18
8 ml	4.31	3.04	1.2315	80	1.49	21	1.458	20
10 ml	4.26	2.98	1.218	79	1.488	24	1.649	21
Distilled Water	7	6.35	1	-	1.335	36.38	2.0521	-
2 ml	4.08	4.13	1.265	79	1.488	20	1.428	21
4 ml	3.89	3.67	1.212	78	1.486	22	1.503	22
6 ml	4.6	3.13	1.2396	78	1.486	19	1.328	22
8 ml	3.84	3.21	1.194	74.5	1.476	20	1.347	25.5
10 ml	3.82	3.19	1.194	71	1.468	34.5	2.324	29

Studying the rheological behavior of honey is significant for applications related to handling, storage, processing, quality control, and sensory analysis. Furthermore, the rheology of honey can be associated with its chemical composition. [5, 10, 18]

Apparent viscosity of honey was plotted against shear rate for the four types of honey with the different adulterants respectively at room temperature. The relation between viscosity and shear rate can be expressed as: [19]

$$\mu = k\gamma^{n-1} \quad 3.1$$

Where: μ: is the apparent viscosity in Pa.s.
k: is the consistency index in Pa.s^{-n}.
γ: is the shear rate in s^{-1}.
n: is the flow behavior index.

The relation between shear stress and shear rate determines the flow characteristics of pure and adulterated honey; plotting shear stress against shear rate for pure honey and adulterated samples concludes the type of fluid the samples exhibits as the numerical values of consistency index and flow behavior index can be calculated and thus concluding the type of fluid. Shear stress can be obtained by the formula: [15, 19]

$$\tau = k\gamma^{n} \quad 3.2$$

Where: τ: is the shear stress in Pa.
k: is the consistency index in Pa.s^{-n}.
γ: is the shear rate in s^{-1}.
n: is the flow behavior index.

Figure (1) shows the effect of shear rate on the shear stress of black seed honey adulterated with different volumes the adulterants compared to pure and purchased samples. The results determined that shear stress of pure and purchased honey samples were higher than the adulterated samples. Shear stress increases with the increase of shear rate -directly proportional- The flow behavior index indicates that the samples exhibit shear thinning flow behavior to nearly Newtonian flow. The same trend was observed for all honey types studied as illustrated in figures (3.2), (3.3) and (3.4).

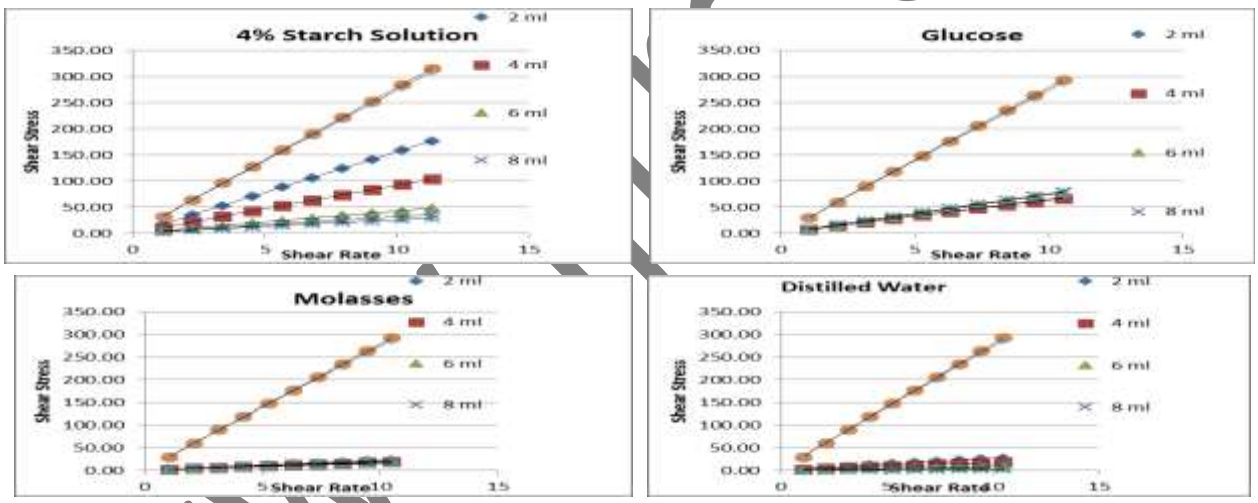

Fig. 3.2 Shear Stress versus Shear Rate of Clover Honey with Adulterants

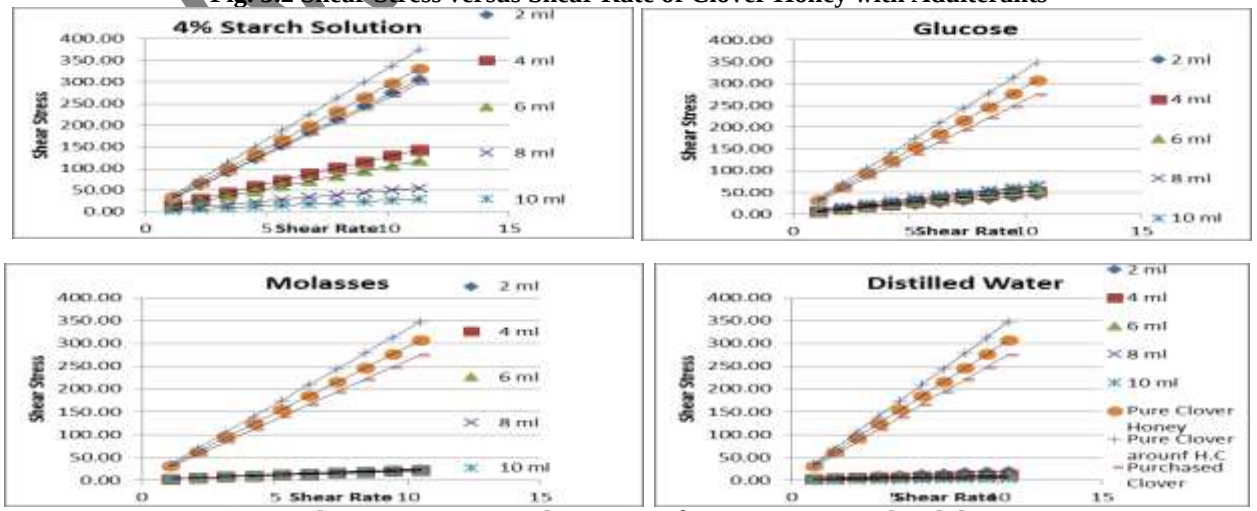

Fig. 3.3 Shear Stress versus Shear Rate of Desert Honey with Adulterants

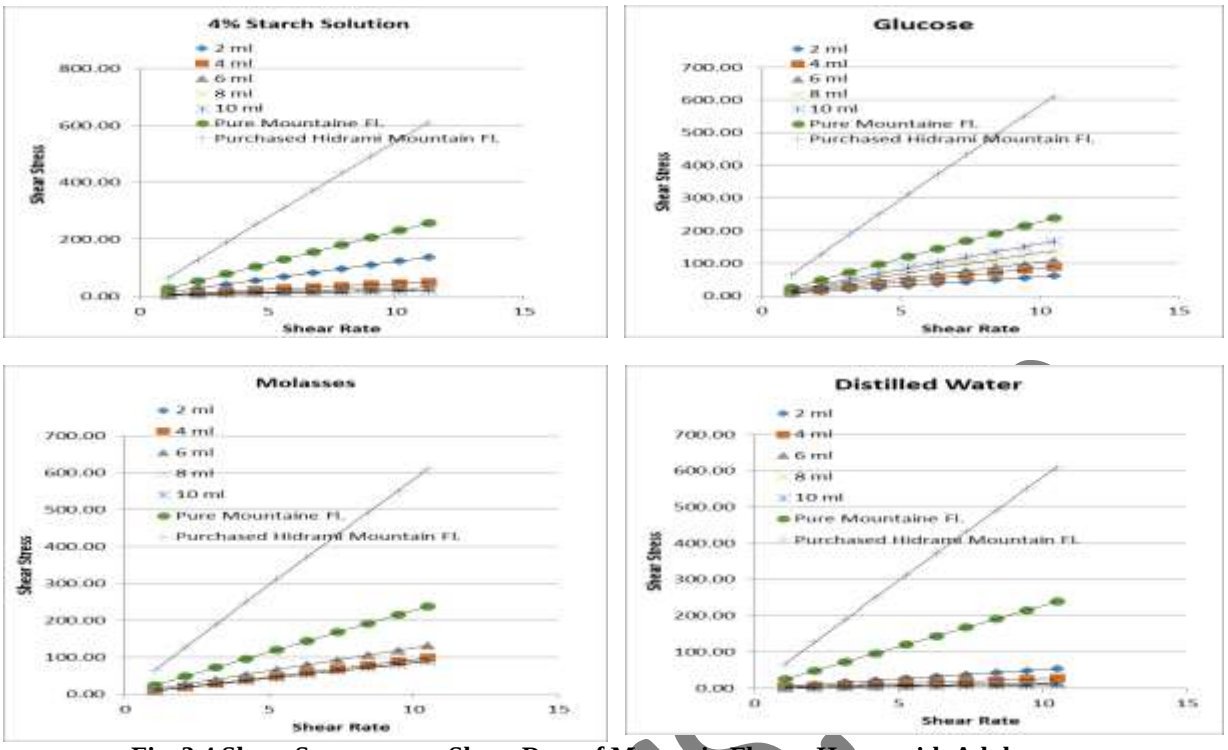

Fig. 3.4 Shear Stress versus Shear Rate of Mountain Flower Honey with Adulterants

3.3 Combined Effect of Shear Rate and Volume of Adulterant on Shear Stress of Samples

The effect of shear rate and volume of adulterant on the shear stress of honey can be combined in a single equation formulated by data analysis as shown in table (3.5). Volumes of adulterant with negative powers were omitted of the equation as its effect can be neglected. The equation can be expressed as follows:

$$\tau = k\, V^{a}\, \gamma^{b} \qquad 3.3$$

Where: τ: is the shear stress in Pa.

γ: is the shear rate in s^{-1}.

V: is the added volume of adulterant in ml.

k, a and b: are constants.

Table-3.5 Values of Constants for Different Honey Types

	Black Seed Honey				Clover Honey				Desert Honey				Mountain Flowers Honey			
	k	A	b	R^2	k	a	b	R^2	k	a	b	R^2	k	a	b	R^2
Starch Solution	40.027	0	0.9698	0.9855	81.8978	0	0.987	0.953	30.055	0	0.85	0.961	32.145	0	0.861	0.989
Glucose	6.382	0.104	0.97	0.997	3.836	0.306	0.924	0.99	10.151	0	0.95	0.986	4.102	0.6	0.967	0.997
Molasses	3.202	0	0.899	0.995	2.657	0	0.938	0.989	2.25	0	0.91	0.98	10.51	0	0.98	0.957
Distilled Water	11.549	0	0.7846	0.95	5.9303	0	0.812	0.978	4.187	0	0.757	0.972	12.456	0	0.934	0.995

CONCLUSION

The physical properties of four pure honey types (black seed, clover, desert and mountain flower) were measured and compared with purchased samples and adulterated samples.

The apparent viscosities of pure and purchased honey samples were higher than the adulterated samples, shear stress of pure and purchased honey samples were also higher than the adulterated samples. The flow behavior index indicates that the samples exhibit shear thinning flow behavior to nearly Newtonian behavior. The effect of adding different adulterants to pure honey -four types of honey- was studied at shear rates 1.1308, 5.6544, 11.3088s^{-1}; the results showed that the apparent viscosity decreases as volume of adulterants increase for all the studied shear rates. Rheological properties of honey can be used to discover honey adulteration, as the volume added increases the viscosity decreases.

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