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STUDY OF QUALITY PARAMETERS OF JOJOBA OIL IMPORTANT FOR PRODUCTION OF VALUE ADDED PRODUCTS

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ABSTRACT

Jojoba oil and its derivatives have potential for uses in diverse products as cosmetics, pharmaceutical preparations, foam control agents, paint industry, candle industry and as food products. It is a source of long chain alcohols and acids with double bonds in slightly different positions from those in other natural fatty acids. Due to high flash and fire points, Jojoba oil can be used in the manufacture of high-pressure lubricant, which is required worldwide. Jojoba oil maintains its viscosity at high temperature. It has also higher thermal stability due to high flash and fire points, lower pour point and maintenance of viscosity at high temperatures. These properties can also enhance its worth as a potential component of lubricant if added in small quantity. Because of its pleasant feel on skin and its stability towards rancidity, it could become a standard oil-phase base for the cosmetic industry as well as useful for food product industry. Jojoba oil is relatively shelf-stable when compared with other vegetable oils, so it is used to make ointments, antifoams for industrial uses. It is a source of mono-unsaturated alcohols and acids with chain lengths of 22 and 24 carbons. Due to the alcohols present in it, Jojoba oil is used in the automobile industry as an antifreeze agent. It is oil producing industrial crop, potentially valuable for production of value added products.

Key words: Jojaba oil, Quality parameters, Flash point, Fire point, Pour point.

INTRODUCTION

Jojoba, (*Simmondsia chinensis* (Link) Schneider) is a new oil-producing industrial crop that has attracted much attention in recent years. Jojoba oil, which is commonly known as liquid wax, is colorless and odorless with unique physical and chemical properties[1]. Unlike most other vegetable seed oils, which are triglycerides, Jojoba oil is made of long-chain fatty acids and fatty alcohols with no side branching[2]. This unique chemical configuration accords Jojoba special characteristics unparalleled in the plant

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kingdom. It is similar to sperm whale oil and can be substituted for it in many applications[3]. The most important uses are in the cosmetic industry, as a high temperature high-pressure lubricant, and as a potential low-calorie edible oil. Other possible uses are as an anti-foaming agent in the pharmaceutical industry and in paint, food product and automobile industry. Jojoba oil can easily be hydrogenated into a soft wax and can be used in candle wax, various kinds of polishes, coating material for fruits and pills, and insulation for batteries and electrical wires[4]. Presently, most of the Jojoba seed produced in the United States is used in the high-priced cosmetic industry, and many other potential markets have not been fully developed[5].

Jojoba is being cultivated in different parts of Rajasthan. Jojoba is an important oilseed crop. Its oil is useful for industrial and cosmetic purposes. Jojoba oil differs radically from other vegetable oils, and the absence of triglycerides makes it unique in its composition. Its industrial and agroclimatic importance attracted public attention, when it became known that its seeds contain about 45-55 percent liquid wax with chemical properties similar to those of sperm whale oil. The story of "The little bean that saves big whales" has been popular since 1970's.

Jojoba (*Simmondsia chinensis.* L) is among one of the desert economic plants, and has an immense potential of growing on wastelands, coastal and sand dunes. The oil obtained from it is an ideal substitute for sperm whale oil for a variety of industrial applications, and as intermediate or base oil in pharmaceuticals.

Jojoba oil, which makes up about half the weight of seeds, differs so fundamentally from common vegetable oils and fats that it has its own distinct characteristics. Its chemical structure is that of a long straight-chain ester, whereas the others are triglycerides-branched esters are based on the molecule glycerol[6]. Chemists call it a liquid wax.

Jojoba oil's purity, lack of odor and resistance to rancidity make it a natural base for creams and ointments and its initial market has been in cosmetics. However, it also shows promise as a new basic feedstock for the chemical industry. For example, Jojoba-based lubricants are particularly promising. Properly formulated with additives, the oil has excellent lubricity and a long performance life[7]. Moreover, derivatives of Jojoba oil are thought to have possible use in the preparation of antifoaming agents, detergents, disinfectants, driers, emulsifiers, fifers, plasticizers, protective coatings, resins and surfactants. The process of hydrogenation[8] converts most vegetable oils into semi-solids, but it transforms Jojoba oil into a white crystalline wax. This hard solid has potential as a

candle wax[9]; a polishing wax for cars, floors, furniture and shoes; a coating for fruits and pills; insulation for batteries and wires and an ingredient in chalks, crayons and soaps[10].

Jojoba oil is being investigated for use as a treatment for burns[11], acne and psoriasis. Because of its unusual molecular structure, the oil is a possible low-calorie substitute for conventional food oils, as well as a possible cholesterol-reducing agent. These dermatological and food applications are interesting but highly conjectural possibilities that require much additional study (as well as eventual approval by the U.S. Food and Drug Administration and similar agencies) before they can safely be applied.

Jojoba oil is mainly composed of the straight chain monoesters of the C_{20} and C_{22} alcohols and acids with two double bonds[12], one at each side of the ester group. The oil is biodegradable and non-toxic[13]. Today, Jojoba oil is an expensive component of many cosmetics and hair care products. In addition, its viscosity makes it a good choice over petroleum oil as a high-pressure lubricant. Besides this, Jojoba oil is used in pharmaceuticals as a suitable carrier or coating for some medicinal preparations, stabilizer of penicillin products, inhibitor to growth ot Tubercle bacilli, treatment for acne[13] and hair restorer; and as food related as cooking oil and low calorie additive for salad oil and vegetable oil. By keeping this in mind, the department of land resources, Ministry of Rural Development has established Association of Rajasthan Jojoba Plantation and Research Project (AZORP) at Jaipur.

EXPERIMENTAL

Materials and methods

Jojoba is among one of the desert economic plants, and has an immense potential of growing on wastelands. Since agro-climatic conditions and soil in Rajasthan are similar to areas where Jojoba is found in its natural habitat, the Government of Rajasthan took initiative in cultivation of Jojoba in the state.

For collection of seed samples of Jojoba, healthy plants were first identified and tagged. Seeds were harvested from plants and taken as samples of Jojoba seeds. Two Kg. seeds were collected from all the seven locations for the two consecutive years. Oil from samples of Jojoba seeds was then extracted through cold press, installed by Association of the Rajasthan Jojoba Plantation and Research Project-Jaipur at its Dhand Farm and physico-chemical characteristics of the oil was studied at various laboratories. Seven locations were chosen for two-year research work during the year 2005 and 2006.

L1-Dhand Jojoba Farm of AJORP, District-Jaipur, Rajasthan.

L2-Fatehpur Jojoba Farm of AJORP Tehsil Fatehpur, District Sikar, Rajasthan.

L3-Central Arid Zone Research Institute, Jodhpur, Rajasthan.

L4-Jojoba Farm of Mr. Kunji Lal Dhaga, Mathania, Jodhpur.

L5-Jojoba Farm of Mr. Sant Lal Verma. Chak-23PTD The Raisinghnagar Dist-Sriganganagar, Rajasthan.

L6-Jojoba Farm of Mr. Mahaveer Dhaga, Shabili Ghati, Bikaner, Rajasthan.

L7-Jojoba Farm of Mr. Hawa Singh Poonia, Village-Gardana Kala, Tehsil-Chirawa, District – Jhunjhnu.

Various physico-chemical parameters of Jojoba oil were analyzed which were important for production of value added products. These were viscosity, flash point, fire point, smoke point, acid value, composition of various acids and alcohols present in it.

Viscosity is a measure of internal friction in a molecule that is resistance to flow of a liquid under an applied pressure. Viscosity behavior of lubricant is of importance because of the fact that with certain types of motions, the load that an oil film will sustain is related with viscosity.

Flash point of oil is the temperature measured in degrees centigrade, to which it must be heated to give off sufficient vapor to form an inflammable mixture with air under the conditions of the test. The lower is the flash point, the greater is the tendency for volatilization of the oil as the temperature increases.

Fire point is the temperature to which oil must be heated to burn continuously after the inflammable air-vapor mixture is once ignited.

Smoke point is the temperature to which oil can be heated before it smokes. At the smoke point, the oil begins to emit unpleasant odors and impart unsavory flavors to meal. Knowing the smoke point warns about flash and fire points. The smoke, fire and flash points of a fatty material are measures of its thermal stability, when heated in contact with air. The best oils for cooking and frying are those that have a high smoke point i.e. they can be heated at high temperature before smoking. Generally, refined oils have a higher

smoke point than unrefined or cold pressed oils.

During storage, fats may become rancid because of peroxide formation at the double bonds by atmospheric oxygen and hydrolysis by microorganisms with the liberation of free acid. The amount of free acid present, therefore, gives an indication of the age and quality of the fat.

RESULTS AND DISCUSSION

An investigation of data presented in Table 1 indicates that highest mean specific gravity of 0.866 was recorded at L3, L5, L6 and L7 locations and lowest mean specific gravity of 0.863 was recorded at L4 location. Specific gravity is less than one for essential oils and accuracy to third decimal place is necessary for determination of physical property.

Table 1. Specific gravity and viscocity (cps) of Jojoba oil samples collected from different locations of Rajasthan in year 2005 and 2006

Location	Specific gravity			Viscocity (cps)		
	2005	2006	Mean	2005	2006	Mean
L1	0.863	0.864	0.864	37.90	30.00	33.95
L2	0.865	0.865	0.865	37.20	30.00	33.60
L3	0.866	0.865	0.866	36.80	30.00	33.40
L4	0.864	0.862	0.863	36.50	30.00	33.25
L5	0.868	0.863	0.866	35.90	30.00	32.95
L6	0.869	0.863	0.866	36.40	30.00	33.20
L7	0.866	0.866	0.866	38.90	30.00	34.45
SED ±	0.003	0.003		0.133	1.24	
CD 5%	0.008	0.007		0.29	2.702	
CV%	0.537	0.516		0.44	5.064	

Perusal of data given in Table 1 regarding viscosity reveals that highest mean viscosity of 34.45 cps was recorded at L7 location and lowest mean viscosity of 32.95 cps was observed at L5 location.

Viscosity of Jojoba oil is very high and is maintained even at high temperatures, which is an indication that it has an application in other value added products -

Automobile industry

As shown in the Table 2, the alcohols i.e. (C18), (C20), (C22) and (C24) are in high percentage. Jojoba oil containing alcohols can therefore, replace ethylene glycol as antifreeze agent as such or with water or with other solvents. It is used as coolant for preventing deposition and formation of ice on aeroplane wings, as coolant for aeroplane engines.

Paint industry

Chemical analysis of Jojoba oil during the two years of analysis shows that it contains appreciable quantities of higher unsaturated fatty acid like oleic acid, erucic acid, eicosenoic acid, docosadienoic and lignoceric acid (Table 5) having one and two double bonds in them. An investigation of data presented in Table 2 regarding oleic acid percentage of Jojoba oil reveal that highest oleic acid percentage of 15.56 percent was recorded at L5 Location, which was significantly higher as compared to oleic acid percentage of all other locations. During 2006, highest 15.30 percent of oleic acid was recorded at L7 location. Experimental findings regarding eicosenoic acid percentage presented during 2005 reveals that highest eicosenoic acid 52.85 percent was recorded at L1 location. Eicosenoic acid percentage in the year 2006 reveals that highest eicosenoic acid of 50.40 percent was recorded at L1 location. erucic acid percentage in the year 2005 and 2006 indicates that during 2005, highest erucic acid 15.96 percent was recorded at L1 location, which was significantly higher as compared to all other locations and in 2006 highest erucic acid 15.41 percent was recorded at L5 location, which was signicicantly higher over erucic acid percentage of other locations. Docosadienoic acid percentage presented indicate that highest docosadienoic acid 13.20 percent and 13.50 percent were recorded at L2 location during 2005 and 2006 respectively and highest, percentage of docosadienoic acid in both the years was significantly higher as compared to all other locations. Lignoceric acid 12.73 percent and 11.99 percent were recorded at L4 location during 2005 and 2006, respectively. These have the property of slowly absorbing oxygen from air and then polymerizing to from a hard elastic film that is transparent coating, and hence used at making paints and oil cloth.

Table 2. Comparative study of fatty acid composition in Jojoba oil collected from different locations of Rajasthan in year 2005 and 2006

Location	Palmitic acid (%)		(C18) Oleic acid (%)		(C22) Eicosenoic acid (%)		(C22) Erucic acid (%)		Doscosadienoic acid (%)		Lignoceric acid (%)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
L1	0.90	1.10	10.34	9.90	52.85	50.40	15.96	14.77	10.40	12.30	9.55	11.53
L2	1.58	1.56	15.04	13.28	47.34	47.32	12.47	13.42	13.20	13.50	10.36	10.92
L3	1.63	1.60	14.46	15.04	47.50	0.48	15.21	14.16	11.84	11.75	9.36	9.45
L4	0.90	0.90	9.98	14.40	50.99	49.51	15.40	13.20	10.04	0.10	12.73	11.99
L5	1.56	1.54	15.56	9.90	47.72	50.01	14.78	15.41	11.73	11.65	8.64	11.49
L6	1.56	1.55	13.29	14.60	48.01	49.02	12.38	12.70	13.10	11.90	11.65	10.23
L7	2.56	2.00	15.35	15.30	45.35	47.30	15.37	14.92	12.67	11.46	8.89	9.02
SED ±	0.052	0.052	0.012	0.016	0.086	0.011	0.054	0.031	0.091	0.114	0.011	0.009
CD 5%	0.114	0.113	0.026	0.035	0.188	0.024	0.118	0.068	0.199	0.248	0.026	0.02
CV%	4.217	4.37	0.113	0.151	0.219	0.028	0.461	0.264	0.948	1.193	0.144	0.114

With two or more double bonds, these acids possess the property of absorbing oxygen and drying takes place much more readily as compared to those acids, which have non-conjugated double bonds in them. Probably, the drying effect involves the addition of oxygen to the unsaturated linkages present in acid of the oil and some amount of polymerization. This makes Jojoba oil especially useful in chemical Industry.

Candle industry

Perusal of data presented in Table 3 revealed that lowest mean flash point 299ºC was recorded at L7 location and highest flash point 307ºC was recorded at L5 location. Highest mean fire point 348.50ºC was recorded at L3 and L5 locations and lowest mean fire point of 343.50ºC was also recorded at two places i.e. locations L2 and L7. Similarly findings of smoke point presented in Table 4 indicate that lowest mean value of smoke point 197.5ºC was recorded at L2 location followed by L7, L1, L3 and L6, L5 and L4 locations. Highest mean value of smoke point 201ºC was recorded at L4 location.

The pour point data recorded for two years indicate that highest mean pour point 10.50ºC was recorded at locations L1, L2, L3 and L7 while the lowest mean pour point 10.00ºC was recorded at locations L4, L5 and L6. The pour point is the important property of a sample of lubricating oil. Since the pour point of oil indicates the temperature below which, it is not possible to pour the liquid from a container, it is also indicative to a degree of the temperature, at which lubricating greases, made from such oil, can be forced through pipes or fittings. The values are sufficiently low, making the oil suitable for making candles.

The critical analysis of Tables 3 and 4 reveal high flash and fire points and high smoke point and low pour point values of Jojoba oil which indicate that Jojoba oil, can be used as a pollution free raw material for candle manufacturing industry. Candles are made by mixing stearin mixed with 90 percent wax (which contains some solid alkanes and lower member methane) obtained from petroleum well. Therefore, with increase in temperature, it is gives unpleasant smell with smoke. Jojoba oil contains 50 percent true liquid wax made up of higher fatty acid (Table 2) and alcohol (Table 5), whose flash and fire points are much higher than hydrocarbon, alkane (Table 3). As revealed that the smoke point of Jojoba oil is high, and hence, its smoke is odorless and free from pollution. The household paraffin wax is hardened appreciably by the addition of Jojoba oil. The paraffin's opalescent appearance changes to creamy white giving Jojoba wax important potential market in candle making. It is combustible, smokeless and has low ash content. Melting point of Jojoba oil is high enough that candles do not drop around the edge or melt

during storage in warm climates.

Table 3. Flash point and fire point of Jojoba oil samples collected from different locations of Rajasthan in Year 2005 and 2006

Location	Specific gravity			Viscocity (cps)		
	2005	**2006**	**Mean**	**2005**	**2006**	**Mean**
L1	300.00	303.00	301.50	349.00	340.00	344.50
L2	301.00	302.00	301.50	345.00	342.00	343.50
L3	302.00	304.00	303.00	350.00	347.00	348.50
L4	305.00	300.00	302.50	352.00	342.00	347.00
L5	304.00	310.00	307.00	349.00	348.00	348.50
L6	304.00	301.00	302.50	351.00	342.00	346.50
L7	299.00	299.00	299.00	347.00	340.00	343.50
SED ±	0.872	0.796		0.796	0.796	
CD 5%	1.901	1.736		1.736	1.736	
CV%	0.354	0.322		0.280	0.285	

Pharmaceutical preparations

Critical analysis of Table 2 reveal that Jojoba oil contains appreciable amout of eicosenoic acid (C_{20-1}), erucic acid (C_{22-1}), oleic acid (C_{18-1}) and other acids. It can also be used for making effective creams, lotions etc.

Like amino acids, some unsaturated fatty acids are very essential like C_{18-1}. They are not synthesized in the body though they are very essential for life and health; its deficiency causes eczema, derangement of kidney function and disturbances in the reproductive systems.

Jojoba oil and its halogenated derivatives are stable to radiations and thermal treatment and do not become rancid as shown in Table 6 that its acid value is less than one. Their physical and chemical properties make possible their application on skin for cosmetic use and treatment of various dermatological conditions. The lack of toxicity is the reason to use it for dermatological processes of high cosmetic and aesthetic significance.

The wax is composed entirely of esters of high molecular weight straight chain mono ethylenic acids and mono ethylenic alcohols (Tables 2 and 5). It is chemically pure, as after simple refining (filtration through fuller's earth), it contains no resins, tars, alkaloids or glycerides.

It resembles chemically such waxes as bees wax and spermaceti, which are used as vehicles for drugs. Bees wax is composed of long chain esters (72%) as myricyl palmitate and palmito oleate. Spermaceti wax is composed of esters (98%) mainly cetyl palimitate.

Sperm whale oil has long been valued for controlling foam in industrial fermentations. Jojoba oil also has excellent antifoam properties. According to Pathak[19], comparative tests have shown that Jojoba oil could also be an excellent antifoam agent[19]. In a couple of experiments, the yield of penicillin unexpectedly increased by more than twenty percent, when Jojoba oil was substituted for sperm oil.

Table 4. Smoke point (ºC) and pour point (ºC) of Jojoba oil samples collected from different locations of Rajasthan in Year 2005 and 2006

Location	Specific gravity			Viscocity (cps)		
	2005	2006	Mean	2005	2006	Mean
L1	199.00	200.00	199.50	10.00	11.00	10.50
L2	197.00	198.00	197.50	11.00	10.00	10.50
L3	200.00	200.00	200.00	10.00	11.00	10.50
L4	201.00	201.00	201.00	10.00	10.00	10.00
L5	199.00	202.00	200.50	10.00	10.00	10.00
L6	200.00	200.00	200.00	10.00	10.00	10.00
L7	198.00	198.00	198.00	11.00	10.00	10.50
SED ±	0.856	0.556		0.963	0.778	
CD 5%	1.865	1.212		2.099	1.696	
CV%	0.527	0.341		11.472	9.272	

Table 5. Comparative study of various alcohol composition in Jojoba oil collected from different locations of Rajasthan in year 2005 and 2006

Location	C16 Alcohol		C18 Alcohol		C20 Alcohol		C22 Alcohol		C24 Alcohol	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
L1	0.98	0.98	1.08	1.10	43.78	43.29	45.66	45.80	8.50	8.70
L2	1.01	0.98	1.06	1.09	43.79	43.93	45.74	45.60	8.40	8.45
L3	1.00	0.89	1.09	1.08	43.52	43.25	45.89	45.98	8.50	8.70
L4	0.99	0.95	1.10	1.09	43.78	43.56	45.73	45.90	8.40	8.50
L5	0.89	0.97	1.07	1.06	43.86	43.67	45.88	45.70	8.30	8.60
L6	0.88	0.96	1.06	1.08	43.79	43.35	45.87	45.80	8.40	8.70
L7	1.02	0.98	1.08	1.07	43.76	43.85	45.64	45.60	8.50	8.50
SED ±	0.024	0.01	0.009	0.01	0.009	0.015	0.012	0.109	0.172	0.128
CD 5%	0.054	0.023	0.02	0.023	0.021	0.033	0.027	0.239	0.376	0.279
CV%	3.143	1.374	1.053	1.244	0.028	0.044	0.033	0.294	2.51	1.839

Table 6.Acid value (mg/g KOH) of Jojoba oil samples collected from different locations of Rajasthan in year 2005 and 2006

Location	Just after the extraction of oil		
	2005	**2006**	**Mean**
L1	0.54	0.42	0.48
L2	0.66	0.45	0.56
L3	0.89	0.40	0.65
L4	0.62	0.24	0.43
L5	0.76	0.35	0.56
L6	0.85	0.29	0.57
L7	0.63	0.28	0.46
SED ±	0.015	0.012	
CD 5%	0.033	0.026	
CV%	2.637	4.355	

As an antifoam agent in the production of penicillin, Jojoba oil is far superior to any other known product. Because of its purity and indigestibility, it does not interfere with biological processes. Jojoba oil has wide applications as a carrier for medications as well as directly as a treatment for rashes, cuts, acne, psoriasis and neurodermatitis. Jojoba oil may be used as a lubricant for artificial hearts, as it is non-contaminating and 100 percent pure.

Food products

An examination of data presented in Table 6 regarding acid value of Jojoba oil indicate that highest mean acid value of 0.65 mg/g KOH was recorded at L3 location followed by L6, L5, L2, L1, L7 and L4 locations. Lowest mean acid value of 0.43 mg/g KOH was recorded at L4 location. The acid value of Jojoba oil is less than one.

The data in Table 7 indicate that this value does not change over a period. The lowest mean value 0.55 mg/g KOH was observed at location L1 and highest 0.89 mg/g KOH at L3. The values being less than one and that also maintaining over a period of 18 months after the extraction of oil. means, it can be stored for an indefinite period and will never turn rancid without refrigeration or special handling. Shelf life of indeterminate duration is highly important for the food product industry.

Table 7. Acid value (mg/g KOH) of Jojoba oil samples collected from different locations of Rajasthan in 2005 just after extraction, 6, 12 and 18 month after extraction

Location	Just after extraction	6 months after extraction	12 months after extraction	18 months after extraction	Mean
L1	0.54	0.55	0.55	0.55	0.55
L2	0.66	0.66	0.66	0.67	0.66
L3	0.89	0.89	0.89	0.89	0.89
L4	0.62	0.62	0.62	0.63	0.62
L5	0.76	0.77	0.77	0.78	0.77
L6	0.85	0.85	0.86	0.86	0.86
L7	0.63	0.64	0.64	0.55	0.62
SED ±	0.015	0.014	0.013	0.013	
CD 5%	0.033	0.030	0.028	0.03	
CV%	2.637	2.415	2.27	2.372	

Jojoba meal

The meal that remains after the oil has been extracted as a potentially valuable by product. It contains about 30 percent protein as well as carbohydrate and fiber. Of the essential amino acids in its protein, lysine content is quite good.

CONCLUSION

The observations recorded in the tables are in agreement with the varied uses of Jojoba oil in value added products. It is a liquid wax - along chain molecule wax ester, which means that it has all the properties of the finest oils but many more uses. Since it is a liquid wax and is hypoallergenic, non-contaminating, non-toxic and will never turn rancid (Table 6 and 7), along with its high viscosity (Table 1), which never breaks down under high temperature and pressure, makes it a unique and valuable oil. The oil has radically different chemical structure from any other known oils. Jojoba esters are composed entirely of straight chain alcohols (Table 2). Both acid (Table 2) and alcoholic portions (Table 5) have C_{20} or C_{22} carbon atoms and each has one double bond. Waxes of this type are difficult to synthesize.

Besides a good lubricant used in high-speed machinery, it is used in tool work and metal cutting. A dihydric alcohol, ethylene glycol is used as antifreeze in automobile radiators because of low freezing mixture with water. Jojoba oil also contains alcohols (Table 5), which can replace ethylene glycol as antifreeze agent as such or with water or with other solvents.

Jojoba oil has the capability to substitute tung, linseed and perilla oils in the manufacture of paint industry, as the acids present in Jojoba oil have one and two double bonds in them. Their property of absorbing oxygen from air and then polymerizing to from a hard elastic film makes it suitable for industrial application.

High flash and fire points and high smoke point values (Table 3 and 4) of Jojoba oil indicate that Jojoba oil can be used as a pollution free raw material for candle manufacturing industry.

Acid values of Jojoba oils (Table 6) is less than one and it never turns rancid (Table 7) whereas other oils like olive oil, almond oil etc., which have triolein, get rancid on exposure to light and storage. These rancid oils are non - drying oils because under the influence of microorganisms, the oil is decomposed into saturated and unsaturated acid and glycerol. These unsaturated acids are oxidized into aldehydes. As Jojoba oil is not a triglyceride and hence, it does not decompose into glycerol and the acids changing into aldehyde that is why, it does not turn rancid.

Jojoba oil and its halogenated derivatives are stable to radiations and thermal treatment and do not become rancid (Table 6). Their physical and chemical properties

make possible their application on skin for cosmetic use and treatment of various dermatological conditions.

The results depicted regarding the keeping quality of Jojoba oil are in agreement with the experiments conducted by the University of California at River ride that if a large number of samples were fried in the same Jojoba oil, the last sample was as fresh as the first one because of its non-rancidity. Jojoba oil also contains a natural appetite suppressant called simmondsin. As a diet aid, it can be made into anything from candy-like bars to a chocolate-like beverage.

REFERENCES

1. J. Lewkowitsch, Chemical Technology and Analysis of Oils, Fats and Waxes, pp. 419-24.
2. Anonymous, National Research Council, Jojoba, New Crops for Arid Lands, New Material for Industry, National Academy Press, Washington, D. C. (1985).
3. V. K. Bhatia, (2001), Potential of Jojoba Oil for New Energy Applications, Paper Presented by Ex-Scientist of Indian Institute of Petroleum in the National Seminar on Jojoba held at Jaipur on 19-20 February and published in Souvenir on National Seminar on Production, Marketing and Processing of Jojoba (2001).
4. J. Brown and K. Dwyer, The Jojoba Potential; An Overview, Proc. 7th Inter. Conf. on Jojoba and its Uses, Ed. A. R. Baldwin, A. O. C. S. Illinois, 343-353 (1988).
5. Anonymous, Souvenir on National Seminar on Production, Marketing and Processing of Jojoba held at Jaipur (Rajasthan) India from February 19-20, (2001).
6. T. K. Miwa, Jojoba Oil Wax Esters and Derived Fatty Acids and Alcohols, Gas Chromatographic Analysis, J. A. O. C. S., **48**, 259 (1971).
7. Anonymous, Modern Technology of Petroleum, Greases, Lubricants and Petrochemicals, National Institute of Industrial Research, Delhi, pp.72-80.
8. J. H. Brown Jojoba: A Report on the Current Status of the Jojoba Industry, including a Discussion of Several New Derivatives that Should be of Interest to Cosmetic Formulators, HAPPI, October (1984).
9. T. K. Miwa, Chemical Aspects of Jojoba Oil, A Unique Liquid Wax from Desert Shrub. *Simmondsia californica*, Cosmetics and Perfumery, **88**, 39 (1973).
10. T. K. Miwa and J. W. Hagemann, Physical and Chemical Properties of Jojoba Liquid and Solid Waxes, Proceedings from the Second International Conference on Jojoba and its Uses, Ensenada, Baja California, Mexico (1976).

11. W. Johnson Jr., Final Report on the Safety Assessment of Jojoba oil and Jojoba Wax, J. Amer. Coll. Toxicol., 11(1) pp. (1992).

12. J. Wisniak, The Chemistry and Technology of Jojoba oil, American Oil Chemists Society, Champaign. IL, 43 (1987).

13. G. F. Spencer and G. R. List, Specifications, Physical Properties and Methods of Analysis for Jojoba Oil, Proceedings from the Seventh International Conference on Jojoba and its Uses, American oil Chemists' Society, Champaign. IL (1988).

14. S. G. Pathak, R. F. DePhilipps, R. M. Kerwin, L. L. Hepler, W. Tien and H. E. Alburn, Jojoba Consejo Nacional de Ciencia Tecnologia, Insurgents Sur., 1677, Z. P. (20, D). F. Mexico City, Mexico (1978).

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