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The Effect of Hydrogenation on Physical and Chemical Characteristics of Soyabean Oil

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ABSTRACT: Hydrogenation of oils might be considered as the largest reaction in the edible oil industry. The reaction consists of the addition of hydrogen at the double bounds of fatty acids. Although for some reasons this might be considered a desirable reaction but for some others it might create problems in the food and nutrition chain circle due to the formation of saturated and trans fatty acids. Soyabean oil was selected and hydrogenated and physical and chemical properties consisting of acid value, percent free fatty acid, peroxide value, color, Iodine value, induction period, saponification value, percent non saponifiable matter and fatty acid composition were determined and evaluated before and after hydrogenation process. Hydrogenation process has caused reductions in color, Iodine value, unsaturation with increased formation of some trans fatty acids.

Keywords: *Fatty acid, Hydrogenation, Iodine value, Soyabean oil.*

Introduction

Hydrogenation process of vegetable oils was developed by Wilhelm Norman in the early 1900s and now might be considered as the largest operation in the edible oil industry. The process is the addition of hydrogen at the double bond of fatty acid chains in order to form some solid or semisolid fats, increase the melting point of the fatty substrate with improved oxidative stability and reduce the color by the addition of hydrogen at the conjugated chain of carotenoids. Although the above explained matters are desirable in some formulated foods or the use of hydrogenated fats, but some undesirable products such as saturated and trans fatty acids are formed.

Approximately one-third of all edible oils in the world are hydrogenated. Unresolved nutritional questions concerning trans fatty acids in the hydrogenated fats are prompting producers to employ softer and more selective operations to reduce the trans fatty acids or look for alternatives such as interesterification, for instance hydrogenation process has been developed using low-temperature electro catalytic process of edible oils that resulted in less trans isomer formation (Fitch, 1994). Other works concerned to improve the hydrogenation performance has centered to some extend on new generation of catalysts and also controlling and selecting the hardening conditions (Fitch, 1994).

Soyabean dominate and probably will continue to dominate world vegetable

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protein and oil market in spite of the competition from other oil seeds. The reason for such dominance includes factors as favorable agronomic characteristics, reasonable return to farmer and processor, high quality protein meal for animal feed, high quality edible oil products and the plentiful, dependable supply of soyabean available at competitive prices (Pryde, 1980). Therefore the popularity and success of soyabean is not only due to its oil content but also its high yield of high quality meal. Soyabean oil contributes a major share of world markets where it is sold for salad and cooking oils, shortening and margarine.

Soyabean oil has both advantages and disadvantages when compared to other vegetable oils, namely high level of unsaturation and can be hydrogenated selectively for blending with semi solid and liquid oils particularly containing low level of palmitic acid. The oil contains high level of natural antioxidants namely γ,δ and α tocopherols where γ-tocopherol is the predominant tocopherol present. The oil contains 7-8% linolenic acid, which is responsible for favour and odour reversion and lower oxidative stability. However partial and selective hydrogenation can be easily carried out to reduce linolenic acid concentration with a consequent greatly improved stability (Minshew, 1977).

The phospholipids are present in relatively large amounts and must be removed by processing due to their commercial use in the food formulation and their inactivation of nickel catalyst during hydrogenation process and their possible contribution to fishy and flavor reversion as well as emulsification properties (Ghavami, 1982).

Due to the fact that soyabean is one of the major imported product to Iran and the fact that some of the extracted oil is hydrogenated, it is the aim of this investigation to evaluate the effect of hydrogenation on physical and chemical characteristics of this oil.

Materials and Methods

Soyabean oil in the form of bleached and hydrogenated were obtained from a local refining edible oil factory. All the chemicals were purchased from Merck chemical company of Germany.

The hydrogenation operation was carried out at 150-180 ◦C and 1.5-2.0 bar pressure with nickel catalyst at 0.04% concentration and agitation at 80 rpm.

The color of the oil and fat was determined by using Lovibond apparatus employing 1 inch cell according to AOCS method, number cc13e-92.

Percent free fatty acid and acid value were determined by dissolving the oil in a mixture of diethyl ether and ethanol and titrating the mixture with 0.01 N potassium hydroxide using phenolphthalein as an indicator according to AOCS method number 940.28.

The induction period was determined by Rancimat apparatus model 743 at 110◦C with an air flow rate of 20 1/h according to Haji Hoseini *et al*. (2014).

Peroxide value was determined by dissolving the oil in a mixture of acetic acid and chloroform and titrating the mixture with anhydrous sodium sulphate using starch as an indicator according to AOCS method number cd8-53.

The non saponifiable matter was isolated by saponification of the oil with alcoholic potassium hydroxide followed by the extraction of the non saponifiable matter with ether according to AOAC method number 933.08.

Fatty acid composition of the oil was determined by the formation of fatty acid methyl esters according to AOAC standard method number 969.33 and injection of the methyl esters onto a GC equipped with a flame ionization detector and a 30m DEGS capillary column according to AOCS standard method number 91-Cele. The

Iodine value indicating the degree of unsaturation was determined according to the equation presented by Kamazani *et al*. (2014).

Statistical analyses were carried out using SPSS software and Duncan test. Analysis of variance (ANOVA) was applied to detect significant differences.

Results and Discussion

Table 1 present some chemical and physical characteristics of soyabean oil before and after hydrogenation operation.

The peroxide value of the oil has been reduced slightly after hydrogenation. This might be due to the disintegration of hydroperoxide and the possible discharge of artefacts at elevated hydrogenation temperature. The hydrogenation of the oil at the same time might saturate some fatty acids and transfer them to a more stable form that are resistant to oxidation chain reaction. Acid value or percent free fatty acid, an indication of hydrolytic rancidity has been reduced due to the possible evaporation of the free acid with low molecular weight namely free palmitic at hydrogenation temperature. A firm explanation to this small reduction is the absorption of free unsaturated fatty acid on the surface of the nickel catalyst. Here the higher the unsaturation the higher affinity is observed for absorption. Soyabean oil has considerable quantities of unsaturated fatty acids namely oleic, linoleic and linolenic acids. The saponification value of the hydrogenated fat has been decreased slightly due to saturation with hydrogen that has consequently increased the molecular weight of the fatty acids. The amount of the nonsaponifiable matter has been reduced slightly due to the losses of tocopherols and possible changes of sterols to steroidal hydrocarbon during hydrogenation and post bleaching operations. Iodine value and indication of unsaturation has been decreased considerably in the hardened fat. The considerable increase in the induction period is due to the saturation of unsaturated fatty acids and the presence of tocopherols. Soyabean oil is a rich source of tocopherols particularly γ and δ tocopherols that exhibit better antioxidant activities than α form that shows better vitamin E potency (Ghavami, 1982).

Although the major part of the coloring matter has been removed prior to hydrogenation in the bleaching stage, but hydrogenation operation has caused the saturation of carotenoids with a considerable reduction in the intensity of both red and yellow colors.

Figure 1 presents the fatty acid composition of soyabean oil prior and after hardening.

Table1. Soyabean oil characteristics before and after hydrogenation operation

Properties	Before hydrogenation	After hydrogenation
Peroxide value (meq/kg)	3.50	3.00
Acid value (mg/g)	0.65	0.44
Free fatty acid (%)	0.33	0.22
Nonsaponifiable matter (%)	3.85	3.60
Iodine value (g Iodine/100 g oil)	130.00	29.90
Saponification value (mg KOH/g)	192.50	192.00
Induction period (h at 110°C)	3.75	95.04
Red color	0.80	0.10
Yellow color	9.00	2.00

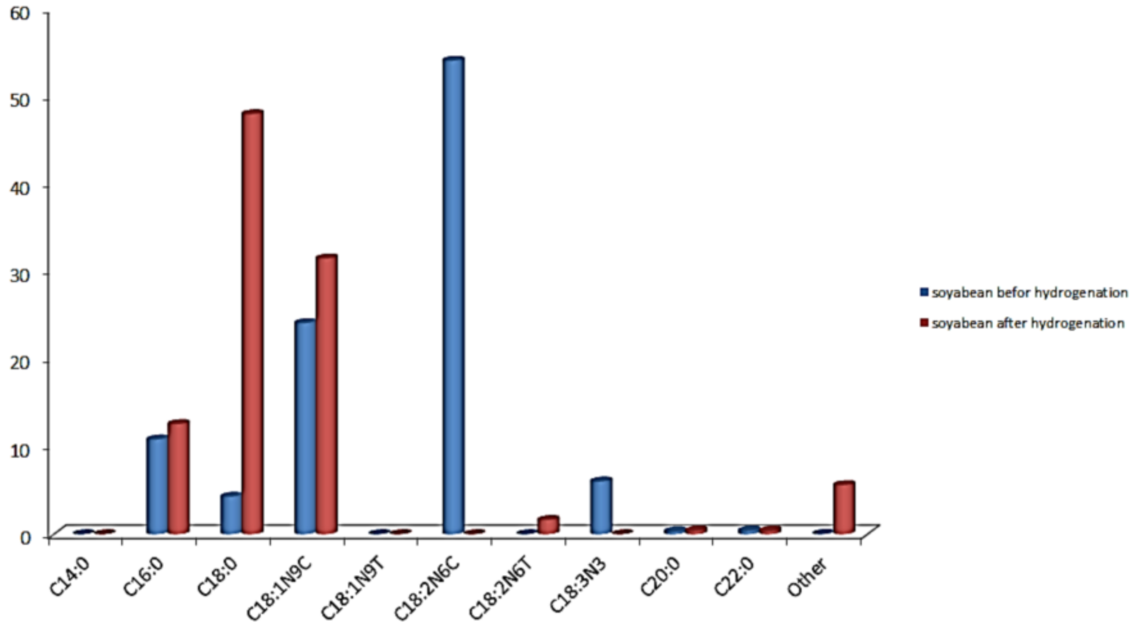

Fig.1. Fatty acid profiles of soyabean and hydrogenated soyabean oils

Isomerization occurs during hydrogenation with some of the cis double bonds migrating along the fatty acid chain and some conversion to the trans configuration. The trans fatty acids have higher melting point and many cis formed isomers have elevated melting points as compared to the original cis acids that were present in the oil. Some factors namely reaction temperature, hydrogen concentration, agitator speed and catalyst concentration among others affect the hydrogenation process. The degree of trans formation depends on variations of these factors (Fitch, 1994).

Average ranges of trans fatty acid content in margarines based on hydrogenated vegetable oils are 7-39% in some countries in Europe and America as indicated by Berger (1993).

Recent articles warns the consumers about trans and saturated fatty acids in fats and fat based products such as margarine.

As presented in Figure 1 considerable amounts of unsaturated soyabean oil fatty acids are converted to saturated ones. The profile indicates that the process might have been carried out nonselectively since minute concentrations of elaidic and C18:2 acid isomers are formed and the concentration of trans isomers formed are much lower than the hardened fat if selective hydrogenation was carried out.

Figure 1 also indicates that over 48% of the unsaturated fatty acids are converted to stearic acid therefore the column indicated in Figure 1 as others might be isomers or trans acids isomers not identified practically. The results indicate that the hydrogenation of investigated product was carried out to produce specific hardened fat for particular products.

Conclusion

Hydrogenation, the chemical process for adding hydrogen to unsaturated triglyceride esters might be regarded among the tool the industry uses to give fats and oils desired functionality for specific products and is the largest section of edible oil industry. Due to undesirable formation of some fatty acids either in the form of saturated or trans, the industry is always looking for alternations or smother process to reduce the undesirables.

The above investigation has been carried out as a preliminary study on a typical hydrogenation operation that was carried out by one of the industries in Iran to obtain a specific fat with increased melting range for particular products. The product contains approximately 60% saturated and 32% mono unsaturated fatty acids with low concentration of trans that might be employed in bakery and confectionary products to improve their structural characteristics. However factors involved in the hydrogenation operation might be altered to produce products where the quantities of unsaturation might be varied to reach particular specification.

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