Journal of American Science

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Effects of Heat Treatment Parameters on Mechanical Expression of Soya Bean Oil

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Abstract: Experiments were carried out with objectives to determine the various heat treatment parameters for better recovery of oil from Soya bean seeds. The experiments were designed at combinations of heating temperature (70, 80 and 90°C) and heating time (10, 15 and 20 minutes) and were conducted using single chamber screw oil extractor. The effect of independent variables i.e. heating temperature and heating time on oil yield were found significant. The optimum conditions for maximum oil recovery were 90°C heating temperature and 15 minutes heating time.

[Anebi Joseph Garba, Victor Imolemhe Umogbai, Samuel Enyi Obetta, John Okanagba Awulu. **Effects of Heat Treatment Parameters on Mechanical Expression of Soya Bean Oil.** *J Am Sci* 2020;16(9):94-98]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 8. doi:10.7537/marsjas160920.08.

Keywords: Heating, soya bean, oil extraction, parameters

1. Introduction

Vegetable oils and fat has gained popularity in food, cosmetic, soap, pharmaceutical and medical industries for the production of cooking oil and margarine, pomade, toilet soaps, drugs and medical ointment respectively (Olaniyan and Yusuf, 2012). Vegetable oil had made an important contribution to the diet in many countries, serving as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn out tissues, new cells formation as well as a useful source of energy (Grosso *et al*., 1997). Extraction of oil from oilseeds is an important processing operation and is a key step for their commercialization. The extraction process has a direct effect on the quality and quantity of protein and oils obtained. Basically, two methods (chemical and mechanical) are used for this purpose. The chemical method (solvent extraction) in which a solvent, when brought in contact with the preconditioned oilseed, dissolves the oil present in the seed and the separated mixture is later heated to evaporate the solvent and obtain the oil. The method is highly efficient (over 98% oil recovery) and a single extractor can handle very large capacities (up to 400 tonnes per day). The solvent extraction process, in which oil is leached from flakes using hexane, is a popular method which is used to remove/extract oil from soya bean seeds. The solvent extraction plants are expensive and are not generally suitable for smaller catchments in Nigeria. There is also a fire and pollution hazard as it requires large quantities of highly flammable solvents (Yusuf *et al*., 2014). Mechanical screw pressing is the most popular method of oil separation from vegetable oilseeds in the world. Nearly 90 % of the total oilseeds produced in Nigeria are crushed employing this method.

Oilseeds processing by mechanical means involve a very low initial and operating costs compared to the solvent method of oil extraction and are relatively free of any pollution or fire hazardous substances. This method is widely used for oil expression in the developing countries or for high oil content seeds. The mechanical screw presses used in Nigeria are, however, inefficient as they leave 8 to 14 % of the residual oil in the cake and thus, a large quantity of precious edible oil (about 0.6 million tonnes) goes into the deoiled cake. Expression is the process of mechanically pressing liquid or liquid-containing solids, screw presses, hydraulic presses, roll presses and mills (such as sugar cane mills), juice extractors, juice reamers collapsible-plate and frame filter, presses are examples of the wide variety equipment available for expression processing (Khan and Hanna, 1983). The existing traditional method of extraction (known as wet extraction process) involves roasting of the kernels using firewood as fuel, pounding and crushing of the roasted kernels by mortar and pestle or between two stones; mixing the crushed mass with warm water, cooking of the mixed paste in order to obtain the oil by floating; and skimming and drying of the oil by further heating. The method is tedious, time consuming, energy wasting, drudgery-prone, inefficient, and low in yield and poor in quality.

Particle size, heating temperature, heating time, moisture content, applied pressure and pressing time affects the yield of fats and oil during expression

(Khan and Hanna, 1983). For maximum oil recovery and least residual oil in the cake, it is necessary to control these factors during the oil or fat expression process. Inability to control them could lead to failure in getting high yield and good quality fats and oil during expression. Fasina and Ajibola (1989) investigated the effect of moisture content, heating temperature, heating time, applied pressure and duration of heating on the oil yield from conophor nut using a laboratory press. The oil yield at any pressure was dependent on the moisture content of the sample after heating, heating temperature and heating time. High oil yields were obtained from the samples with moisture contents between 8 and 10 per cent (wb) after heating. The maximum oil yield of 66 per cent was obtained when milled conophor nut was conditioned to 11 per cent moisture heated at 65 ^{o}C for 28 min and expressed at a pressure of 25 MPa. The oil expressed under this condition was of good quality with 1.18 per cent FFA. Adeeko and Ajibola (1990) studied the effect of particle size, heating temperature, heating time, pressure and pressing time on oil yield and quality of finely and coarsely shelled groundnut. Oil yield increased with increased pressure up to 20MPa beyond which it either leveled off or decreased. The rate of oil expression increased by an increase in temperature, time of heating and particle size. Heating time at any temperature did not affect the oil yield. About 90 per cent oil was expressed in 3 minutes.

Ajibola *et al*. (1990) investigated the mechanical expression of oil from melon seeds in a laboratory press. The processing variables were particle size, moisture content, heating temperature and heating time. The oil yield was affected by moisture content, heating temperature and heating time. However, the oil yield was mostly dependent on the amount of moisture reduction achieved during heating. The highest oil yield of 80 per cent was obtained at a pressure of 25 MPa when the samples conditioned to initial moisture content of 9 and 15 per cent (wb) were heated to achieve a reduction of moisture content of about 5 per cent. Ajibola *et al*. (1993) carried out an investigation on the effects of heating temperature (40 to 85°C), heating time (5.0 to 27.5 minutes), moisture content (6.1 to 12.0 %) and applied pressure (15 and 20 MPa) on the yield, color, refractive index, and specific gravity of oil expressed from sesame seeds using a laboratory press. The yield of oil was affected but the colour, specific gravity and refractive index were not affected by processing conditions within the range considered. The oil yield was increased with decrease in moisture content of sample after heating. Highest oil yield (based on total mass expressed) of 33.5 % corresponding to an expression efficiency (based on seed oil content) of 65.7 % was obtained when sesame seeds were conditioned to moisture content of 6.1 %, heated at 85°C for 20 min, and expressed at a pressure of 20 MPa. Bamgboye and Adejumo (2011) evaluated the Effects of processing parameters of Roselle seed on its oil yield and stated that generally there was an increase in the oil yield as the heating temperature is increased as it caused the protein to coagulate at a very fast rate thus reducing the viscosity significantly and adjusting the moisture content thereby leading to the release of the oil bound to them. Oil flow was found to be inversely proportional to the kinematic viscosity which decreases with increase in heating temperature thus increase in the ability of the oil to flow.

Heating is essential because it completes the breaking down of oil cell walls, lowers the viscosity of the oil to be expelled, coagulates the protein in the meal and adjusts the moisture content of the meal to the optimum level for pressing. High heating temperatures and long heating times may have negative effects on the quality of expressed oil and cake residue. It is therefore important to identify the optimal heat treatment required for processing soya bean seeds. According to Bamgboye and Adejumo (2011), for maximum oil yield and least residual oil in cake, it is very important to control these conditions during the extraction process. Thus, for efficient mechanical expression, a careful establishment of optimum processing conditions is necessary. There are limited researches on the process parameters necessary for the optimum extraction of soya bean seed oil. Hence the knowledge of the appropriate set of parameters for the extraction of soya bean seed oil will enhance the production soya bean oil. The main objective of this work is to evaluate the effect of heating temperature and heating duration on the oil yield of soya bean seed.

2. Materials and Methods

The soya bean variety, grown in Makurdi, Benue State was used in the study. The well dried grains, having a moisture content of 7.40 % dry basis, were cleaned with an air screen grain cleaner (CIAE, Bhopal, India) and were stored in air-tight metallic containers until the were required for studies. The whole soya bean grains were dehulled in a concentric cylinder dehuller (CIAE, Bhopal, India). The separated husk was blown off by the aspirating fan of the dehuller, and whole splits were obtained for further use. The pretreatment of high temperature short time cooking to the prepare soya bean sample was given by microwave ovum. The extracting of oil from soya bean after subjecting to various pretreatments was done with a horizontal screw type oil extractor. The extractor was operated at stable conditions of 1.0 mm choke clearance, screw speed of 110 rpm and throughput capacity of 83.33 kg/hr. The observations were taken when the extractor achieved the stabilized condition of throughput, oil and cake recovery. The experimental plan followed was as given in Table 1. There were two factors namely, the heating temperature and the heating time. Three levels of heating temperature were achieved by using three temperature settings on a microwave ovum, whereas three levels of heating time were achieved by using three time settings on a microwave ovum. The moisture content of each sample was measured by oven drying method (Baryeh, 2002) and fat content was determined by soxhlet extraction method (AOAC, 2005). The experiments were conducted in triplicates and data obtained from the tests were used for statistical analysis. The statistical analysis was conducted using Minitab 16 software (Minitab Inc.).

2.1 Experimental procedure

Plate 1. Photograph of the soya bean oil extractor

(a) Soya Bean Oil (b) Soya Bean Cake

Plate 2. Photograph of the extracted soya bean oil and soya bean cake

Materials required include weighing balance, measuring cylinder, water, prepared soya bean seeds, cake receiving container and oil receiving container. The extractor powered by an electric motor (5 hp) was set into operation and a known weight (6000 g) of each prepared sample was fed into the machine through the feeding hopper. The continuous helical screw shaft conveyed, crushed, squeezed and pressed the material in order to extract the oil. The oil phase was separated from the solid phase (press cake) by the screen. The oil extracted and the press cake were collected and weighed separately. Clarification was done by decantation and heating to separate the oil from its entrapped impurities. The decanted oil was heated at 80 ^oC to remove moisture and was allowed to cool and then filtered using sieves to obtain refined soya bean oil. From the values obtained, the yield of oil extraction was calculated using equation 1 (Adesoji *et al*., 2012).

$$O_Y = \frac{100\, W_{OE}}{W_{OE}+W_{RC}} \qquad (1)$$

Where; O_Y = Oil yield (%), W_{OE} = Weight of oil extracted (kg), W_{RC} = Weight of residual cake (kg).

3. Results and Discussion

The results of effects of heat treatment of soya bean seeds on the mean oil yield (%) of the soya bean oil extractor are shown in Table 2. The oil yield increased with increasing heating temperatures and also increased with increase in heating time from 10 to 15 minutes and decreased at 20 minutes heating time. The best oil yield of 14.1 % was obtained for the conditions of 90 ^oC heating temperature and 15 minutes heating time. The lowest oil yield of 12.4 % was obtained for the conditions of 70 ^oC and 20 minutes heating time. This temperature trend is in agreement with previous works which attribute this behaviour of oilseed to the fact that heat coagulates the protein and reduces the viscosity of the oil thereby facilitating oil expression process as moisture reduction takes place simultaneously. At higher temperature, prolonged heat treatment causes a substantial moisture loss leading to hardening of oil seed sample which best explains the reason behind the reduction in yield at higher temperature (Alonge *et al.*, 2003; Bamgboye and Adejumo, 2011). This observation conforms to findings on previous works carried out on dika nut (Abidakun *et al*., 2012), groundnut (Olajide *et al*., 2014) and shea kernel (Olaniyan and Oje, 2007). The result is also in line with the work of Ajibola *et al*. (1993) who carried out investigations on the effects of heating temperature (40 to 85°C), heating time (5.0 to 27.5 min), moisture content (6.1 to 12.0 %) and applied pressure (15 and 20 MPa) on the oil yield and reported that the oil yield increased with an increase in heating temperature (40 to 85°C), heating time (5 to 27.5 min) and pressure (15 to 20 MPa) and with a decrease in moisture level (12 to 6%). This implies that, heating process prior to extraction process is recommended for increasing the oil extraction efficiency.

The Analysis of variance (ANOVA) at p≤ 0.05 of the effect of heat treatment of soya bean seeds on the oil yield (%) of the soya bean oil extractor is presented in Table 1 and the Means using F-LSD is presented in Table 2. It was observed that the oil yield was significantly different at the heating temperatures and heating times investigated from the ANOVA. But there was no significant difference when the heating temperatures and heating times interacted, that is, the main effect of heating temperatures is not different from the main effect of heating times and vice versa. From the separation of means, there was a significant difference in the oil yield at all the heating times for all the heating temperatures investigated except the heating temperature of 80 ^{o}C for the heating times of 10 and 20 minutes which are not significantly different (Table 2).

Table 1. Analysis of Variance (ANOVA) of the Effects of Heat Treatment Parameters on the Oil Yield (%) of the Soya Bean Oil Extractor

Sources of Variation	DF	SS	MS	F-cal	F-tab
Heating temperature, θ (^{o}C)	2	2.93556	1.46778	33.58*	3.55
Heating time, T (mins)	2	3.14000	1.57000	35.92*	3.55
θ×T	4	0.13778	0.03444	0.79 ^{ns}	2.93
Error	18	0.78667	0.04370		
Total	26	7.00000			

* - Significant at P ≤ 0.05 ^{ns} - Not significant at P ≤ 0.05

Table 2. Effects of Heat Treatment Parameters on the Mean Oil Yield (%) of the Soya Bean Oil Extractor

Heating temperature, ^{o}C	Heating time, mins		
	10	15	20
70	12.8	13.2	12.4
80	13.0	13.4	12.7
90	13.5	14.1	13.1

F-LSD0.05 = 0.359

4. Conclusions

The experiments were conducted to see the effects of heat treatment parameters on oil expression by screw presses. The oil yield of the extractor was found to be affected by both heating temperature and heating time. As the severity of heating temperature increased, the oil yield increased even at lower heating duration. It was found that oil recovery was positively negatively correlated with the heating temperature and also positively related to the heating duration from 10 to 15 minutes and had negative correlation with heating duration at 20 minutes. The optimum conditions for getting maximum oil expression of natural soya bean oil by screw oil extractor were the heating temperature of 90 ^{o}C and heating duration of 15 minutes. The optimized dependent variables at this condition were estimated as capacity of 88.33 kg/hr, oil yield of 14.1 % and oil recovery of 72.67 %.

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9/24/2020