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Optimization of Process Parameters for Corn Germ Oil Extraction

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ABSTRACT

In this study, oil extracted from corn germs was optimized using Response Surface Methodology (RSM). Effects of preheating temperature and time on the yield and oil quality were investigated.Sixteen experimental runs applying an optimal (custom) design with RSM was employed. The parameters measured were oil yield, saponification value, acid value, iodine value and peroxide value. Statistical analysis with response surface regression showed that the oil yield, acid value, iodine value and peroxide value of corn germ oil were significantly ($p<0.001$) affected with preheating temperature and time. But saponification value affected by $p<0.01$. Based on response surface, optimum conditions were preheating temperature of 110 0 C and time of 8 min. Analysis of variance indicating that the models were adequate for representing the experimental data. The treatments resulted in oil yield ranging from (38.26 to 47.30%), saponification value (209.88 to 219.70 mgKOH/g), acid value (1.12 to 1.68 mgKOH/g), iodine value (92.1 to 122.68 gIodine/100g) and peroxide value (0.6 to 2 meq/kg). Oil extracted from corn germ was successfully optimized using RSM. The regression models obtained has provided a basis for selecting optimum process variables for the recovery of oil using mechanical pressing.

Key words: *Corn germ, Heating temperature,Heating time, Oil yield, Oil quality, Optimization.*

Maize or corn (*Zea mays*) is a plant belonging to the family of grasses (*Poaceae*). It is cultivated globally being one of the most important cereal crops. The maize kernel is a mixtureof maternal tissues (eg. pericarp) and zygotic tissues (eg. embryo, aleurone and endosperm). The maize kernel includes pericarp (6%), endosperm (82%) and germ which are about 12%. The typical maize kernel, on dry weight basis is composed of 61-78% of starch, 6-12% of proteins, 3.1-5.7% of oil, 1.0-3.0% of sugar and 1.1-3.9% of ash. The typical fatty acid profile of a maize kernel contains 57.9% of linoleic acid, <1% of linolenic acid, 25.2% of oleic acid, 11.6% ofpalmitic acid and 1.8% of stearic acid (Langade *et al* . 2013). Dry kernels of grain corn contain low levels of oil (about 4%), but most of the oil is contained in the embryo or "germ" portion of the kernel. Corn germ obtained from wet mills usually contains about 40–50% oil, and corn germ from dry mills usually contains about 20–25% oil (both yields expressed on a dry weight basis) (Moreau *et al.* 2005). Maize oil is comprised of about 86 % unsaturated fats and is a good source of vitamin E, providing 15 % of the daily value per tablespoon. The maize oil is a good choice for high-heat cooking (Deepika and Gagandeep, 2014). It is well documented that de-oiled kernel or meal of corn is better than that of whole grain of corn for poultry feed. If the oil remains in kernel, it is disintegrated in glycerin and free fatty acids; free glycerin acts as purgative in the stomach and intestine of poultry birds and cattle (Uddin *et al* . 2013). The most widely used method of oil extraction is the pressing method in which the raw material bearing the oil are compressed and squeezed in a perforated chamber. Pre-pressing conditions such as particle size, heating temperature, heating time, and moisture content are known to affect the yield and quality of oil during expression (Adeeko and Ajibola, 1990). A study by Moreau and others (2005) showed that the maximum oil yield from dry-milled corn germ was obtained by cooking the germ at 180 0 C for 6.5 min in a conventional oven and 4.5 min in a microwave oven at 1500 watts before pressing. Thus, the main objective of this study was to determine the effect of preheating temperature and time on the yield and quality parameters of oil such as saponification value, acid value, iodine value and peroxide value from corn germs using mechanical pressing method and optimization of process parameters.

MATERIALS AND METHODS

Sample preparation

Samples of wet-milled corn germ (dried at the mill to about 5% moisture) were obtained from a commercial corn wet mill. The germ sample was stored in sealed containers at 4°C. On the day of the pressing, enough germ was removed from cold storage for that day's experiments and the germ was allowed to equilibrate to room temperature, before heating. Inconsistent results were obtained if cold germ was used. Conventional oven heating was conducted by spreading the each germ sample (100 g) in a uniform layer in stainless steel plate and heated for the different times (2, 4, 6 and 8 minutes) at different temperatures (90, 120 , 150 and 180 °C) in a Laboratory Oven.

Oil extraction

After heating, the mass of the heated germ was measured (to determine moisture loss), and the hot germ was immediately poured into a Kitchen model Oil Press (Raj kumar oil expellers, India). The expeller capacity ranged from 1.5-2 kg/h and was powered by a 180 W **.** Heated oilseeds enter one end of the barrel through the feed inlet and are conveyed by the rotating worm assembly to the discharge end. This press is heated with an electrical resistance-heating ring attached around the press head, set by the manufacturer to 100°C. Pressing was conducted at the highest screw speed (50 rpm)

(Raj kumar oil expellers, India)

setting and was conducted using the smallest orifice provided by the manufacturer. The pressing was done for two times yields maximum oil. The crude oil was collected, filtered (Whatman #1 filter paper, 5 cm diameter) in a plastic boxes and the mass of the filtered oil was measured and stored in a cooler (4 °C) until

further analysis. The yields of filtered oil (%) were calculated based on the 100-g fresh weight of germ before heating and were not adjusted for moisture loss.

$$\text{Oil Yield (\%)} = \frac{\textit{Weight of oil}}{\textit{W eight of fresh germ sample}} \times 100 \quad \text{\_\_\_\_\_\_\_(1)}$$

Oil quality determination

The quality parameters (saponification value, acid value, iodine value & peroxide value) of mechanically pressed corn germ oil were determined according to Biochemical methods by Sadasivam and Manikham (2008).

Optimization

The optimal conditions of preheating temperature and time were obtained using a commercial statistical package (Design-Expert 9.0.6, Stat ease Inc., Minneapolis, USA). The optimization process was designed at finding the levels of preheating temperature and time, which could maximize oil yield and saponification value while minimize the acid, iodine and peroxide values.

RESULTS AND DISCUSSION

The results of yield and quality parameters of mechanically pressed oil at different preheating conditions are presented in Appendix A. The effects of oven heating temperature & time on yield and quality parameters like saponification value, acid value, iodine value and peroxide value were studied here.

Oil yield (%):

The oil yield from was ranged from 38.26 – 47.30% (Appendix A). Heat treatments effect on oil yield was significant ($p<0.001$). The 2FI model was found to be the best for predicting the relationship between the preheating conditions and yield of the oil (eq.2). High coefficient of determination R 2 (0.9398) indicated that the model might fit well for the data. Response surface plot

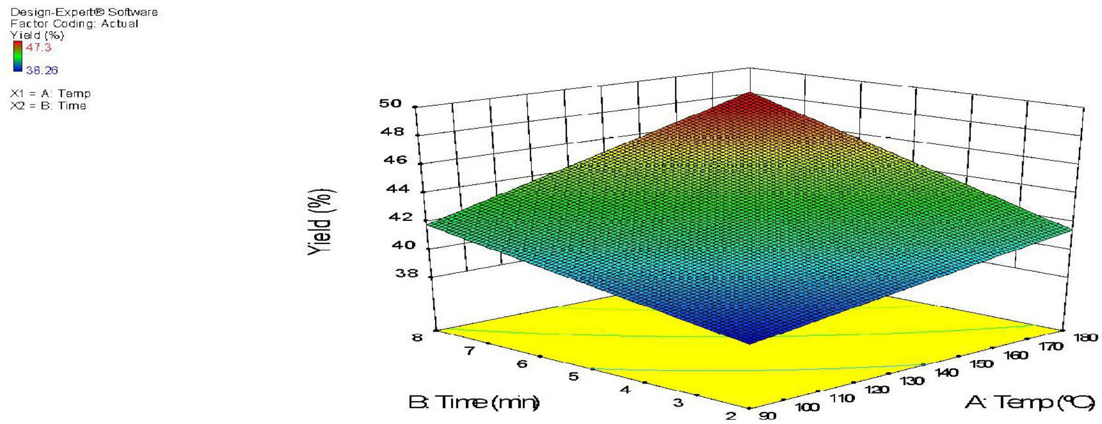

Figure 1. Response surface of oil yield against heating temperature and time.

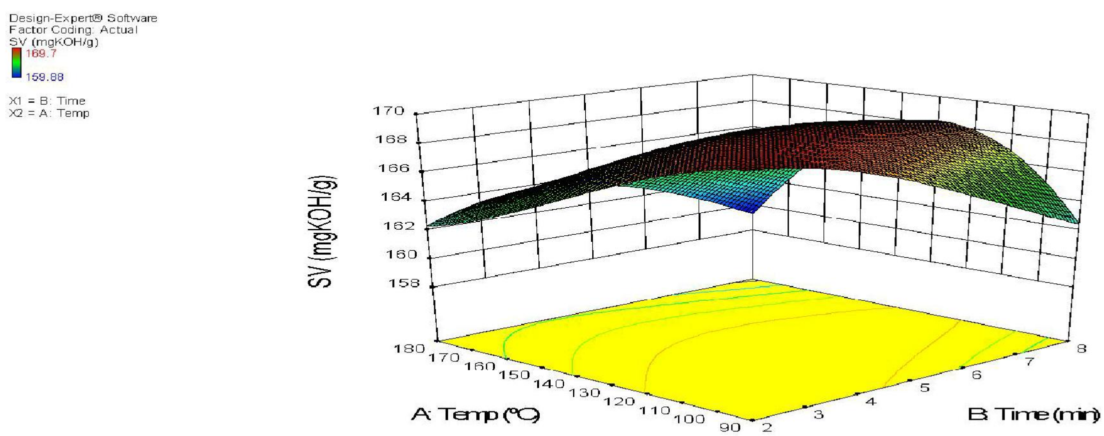

Figure 2. Response surface of saponification value against heating temperature and time

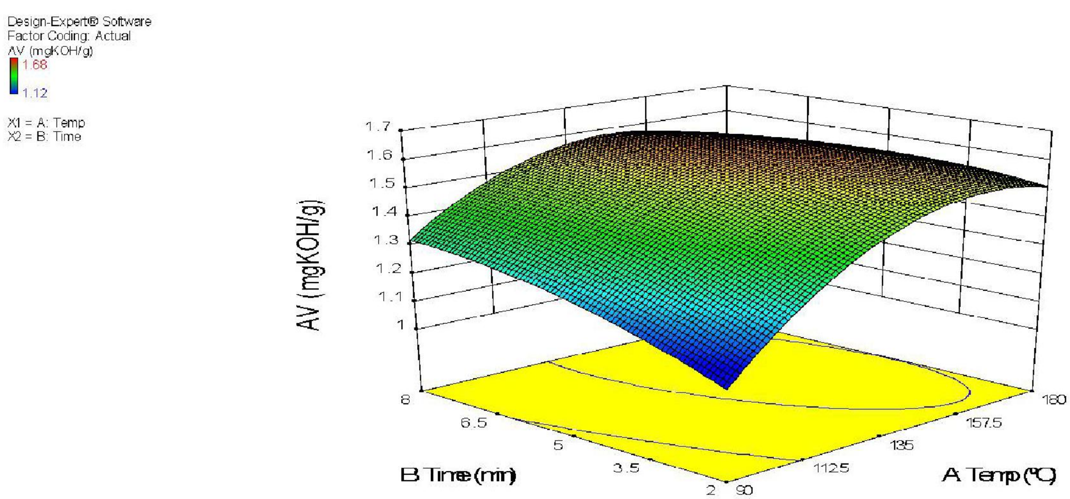

Figure 3. Response surface of acid value against heating temperature and time.

of the relationship is shown in Figure 1. It was observed that oil yield increased with an increased preheat temperature and time. The reason for the increase in yield is that increase in temperature is believed to facilitate the rupturing of oil cell walls, creating a void which serves as migratory space for the contents of the oil bearing cells (Adeeko and Ajibola, 1990). The same result was reported by Tunde-Akintunde *et al.* (2001) for soybean.

Oil yield (%) = 42.4363 + 2.37 A + 2.544 B + 0.79965 AB _______ (2)

The Saponification values were obtained in the range of 209.88 to 219.70 mgKOH/g (Table 1). Saponification is the hydrolysis of fats or oils under basic conditions to produce glycerol and the salt of the corresponding fatty acid. An increase in this value in oil increases the volatility of the oils. In this study, the saponification values decreased with an increase in temperature and the samples differ significantly ($p<0.01$) was observed and the response surface plot of relationship is shown in figure 2. The cubic model was found to be the best for predicting the relationship between the preheating conditions and saponification value of the oil (eq.3). High coefficient of determination R^2 (0.9391) indicated that the model might fit well for the data.

$SV = 218.998 - 2.81031 A + 0.266562 B + 1.0404 AB - 3.74625 A^2 - 1.77469 B^2 - 3.43238 A^2 B - 0.83025 AB^2 + 0.992812 A^3 + 0.587813 B^3$ ______(3)

Acid value (mgKOH/g):

The acid values were obtained in the range of 1.12 to 1.68 mgKOH/g (Table 1). In this study, the acid values increased firstly and then decreased with increasing temperature but increased with time and the samples differ significantly ($p<0.001$) was observed. The quadratic model was found to be the best for predicting the relationship between the preheating conditions and acid value of the oil (eq.4). High coefficient of determination R^2 (0.8760) indicated that the model might fit well for the data. Response surface plot of relationship is shown in figure 3. Adeeko and Ajibola (1990) reported that increasing the temperature of heating increased the lipase activity thus lead to increased free fatty acid and reduced the free fatty acid values at higher temperatures may be due to inactivation of enzymes.

Table 1. APPENDIX A. Yield and quality parameters of pressed oil obtained at different preheat conditions (mean values of 3 replications).

S.No.	A	B	Y	SV	AV	IV	PV
1	90	2	38.26	219.70	1.12	122.68	0.6
2	90	4	40.24	218.30	1.23	116.49	0.6
3	90	6	40.32	215.49	1.23	110.91	0.8
4	90	8	41.88	212.69	1.34	105.50	1.0
5	120	2	39.08	218.30	1.34	112.97	0.8
6	120	4	41.15	219.70	1.45	103.69	1.0
7	120	6	42.44	218.30	1.57	105.15	1.0
8	120	8	43.58	218.30	1.45	95.36	1.2
9	150	2	39.12	214.09	1.45	101.97	1.2
10	150	4	43.14	216.89	1.57	96.65	1.4
11	150	6	43.97	219.70	1.68	95.10	1.6
12	150	8	46.04	215.49	1.68	97.16	1.6
13	180	2	41.16	212.69	1.57	97.77	1.8
14	180	4	44.30	214.09	1.57	96.22	2.0
15	180	6	47.30	211.29	1.45	92.10	2.0
16	180	8	47.00	209.88	1.45	93.21	2.0

Where A = Temperature (^{0}C), B = Time (min), Y = Yield (%), SV = Saponification value (mgKOH/g), AV = Acid value (mgKOH/g), IV = Iodine value (g Iodine/100g), PV = Peroxide value (meq/kg)

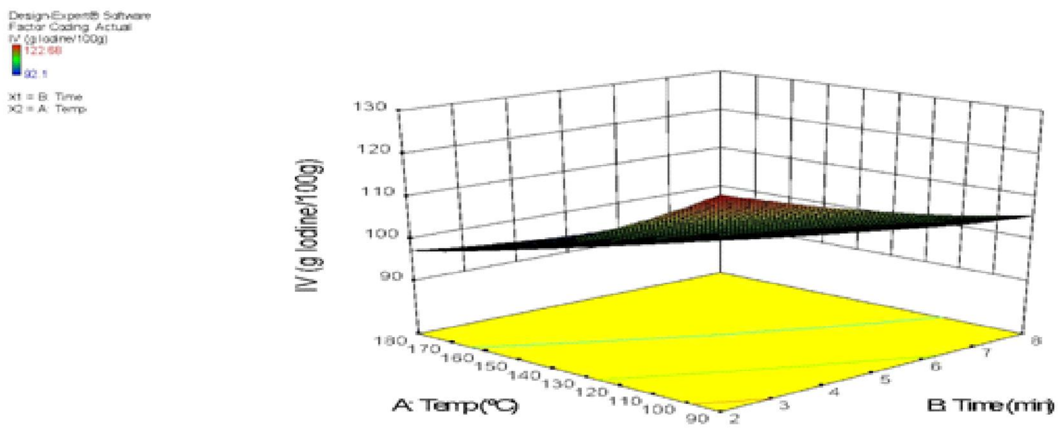

Figure 4. Response surface of iodine value against heating temperature and time.

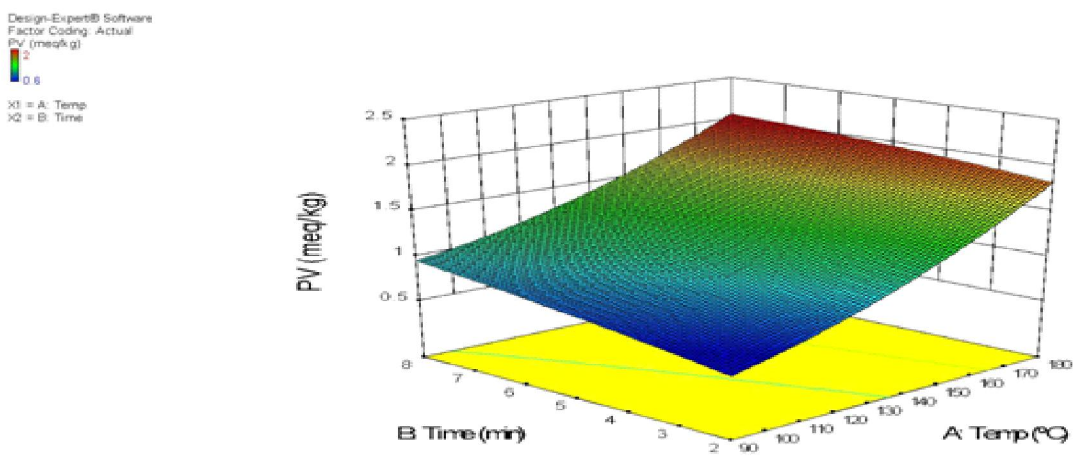

Figure 5. Response surface of peroxide value against heating temperature and time.

The similar was reported by Tunde-Akintunde *et al.* (2001) for soybean oil.

AV = 1.57031+0.147375 A+0.053625 B-0.069075 AB-0.172969 A^2 -0.0492187 B^2 ________(4)

The iodine values were obtained in the range of 92.1 to 122.68 g Iodine/100g (Table 1). In this study, the iodine values decreased with increasing preheating temperatures and the samples differ significantly ($p<0.001$) was observed. The quadratic model was found to be the best for predicting the relationship between the preheating conditions and iodine value of the oil (eq.5). High coefficient of determination R^2 (0.9607) indicated that the model might fit well for the data. The decrease in iodine value with increase in temperature of the seeds is a proof that lipid oxidation had occurred (Joseph, 1997).

IV = 99.7816-9.56738 A-5.33512 B + 3.45037 AB + 3.77297 A^2 + 1.44984 B^2 _______(5)

The peroxide values were obtained in the range of 0.6 to 2 meq/kg. In this study, the increased peroxide values with increased preheat conditions and the samples differ significantly ($p<0.001$) was observed. The quadratic model was found to be the best for predicting the relationship between the preheating conditions and peroxide value of the oil (eq.6). High coefficient of determination R^2 (0.9849) indicated that the model might fit well for the data. Response surface plot of relationship is shown in figure 5. This increase indicates that hydro-peroxides were formed in the oils as a result of oxidation which results the deterioration of oils. This increase has been reported by Adeeko and Ajibola (1990) and Tunde-Akintunde *et al.* (2001).

$PV = 1.225+0.6075\ A+0.1725\ B-0.0495\ AB + 0.140625\ A^2 -0.028125\ B^2$ _________ (6)

Optimum conditions

The optimum value obtained by using software Design-Expert 9.0.6 is 110 0 C and 8 min. At this optimum condition, oil yield, saponification value, acid value, iodine value and peroxide value were calculated as 42.04%, 217.40 mgKOH/g, 1.49 mgKOH/g, 100 g Iodine/100g and 1.12 meq/kg respectively.

CONCLUSION

The results of this study suggested that the oil extracted from corn germs, when refined, can be used as vegetable oil, since the quality parameters of corn oil has been shown to fall within the specified range for vegetable oils. Preheating temperature and time combinations influenced both the yield and the quality significantly at 99% confidence level. Models were developed for predicting the effect of preheating temperature and time on the OY, SV, AV, IV and PV of the oil obtained from corn germ by mechanical pressing. The optimum conditions was preheating at 110 0 C for 8 min which gave 42.04% oil yield, 217.40 mgKOH/g saponification value, 1.49 mgKOH/g acid value, 100 g Iodine/100g iodine value and1.12 meq/kg peroxide value. The optimum process condition produced a comparatively high oil yield with good quality storage stability.

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