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IN recent years there has been increasing interest in the drying of high-moisture soybeans. However, several questions must be answered before the feasibility of such a practice can be ascertained. One potential problem of drying soybeans with heated air is that of maintaining high oil quality during the drying process. This is of utmost importance since soybean oil represents a major portion of the total economic value of the beans. During drying, the beans are exposed to heat, moisture, enzymes and a plentiful supply of oxygen, all of which are known to contribute to the oxidative deterioration of fats and oils. Severe oxidation of edible fats and oils results in the formation of off-flavors and odors, a condition known as rancidity. While it is not likely that a large amount of oxidation would take place during drying, there still may be enough to decrease oil quality. Deterioration of as little as 0.1 percent of the fat may be sufficient to cause rancidity (Swern 1964), and oxidation incurred during drying may also contribute to a decrease in the storage life of the product.

Soybean oil is a polyunsaturated oil being composed mainly of triglycerides of oleic, linoleic, and linolenic acids. Because of its high degree of unsaturation it is particularly susceptible to the development of off-flavors and odors. Soybean oil properties have been studied extensively and are presented in detail by Markley (1950). However, no information is available concerning the behavior of soybean oil contained within the bean. Recently McKnight and Moysey (1971) evaluated the effects of temperature and airflow rate on the quality of dried rapeseed, and similar work is in progress with other seeds. The objective of the study reported here was to determine the effect of harvest moisture content and drying air temperature on the quality of oil extracted from dried soybeans.

INDICES OF QUALITY

Several different indices are used to evaluate the quality of fats and oils. Many of these are described by Markley (1950) and Swern (1964). The four indices used in this experiment were selected on the basis of common use and sensitivity.

The quantity of **free fatty acids** in an oil is a good indicator of its overall quality. They may be formed through hydrolysis or in the advanced stages of oxidation. An excessive amount of free fatty acids lowers the smoke point of an oil and will cause "popping" of the oil during cooking. High quality oils are low in free fatty acids.

Iodine number is an indicator of the number of double bonds present in a fat and is expressed as grams of iodine absorbed by 100 grams of oil. Oxidation consumes the double bonds, and a decrease in iodine number indicates that some double bonds have been used. Oils having high iodine numbers are polyunsaturated and are desired by oil processors, while a lower iodine number is indicative of lower quality.

The potential for development of rancidity is measured by the **peroxide number.** Formation of peroxides is the initial step of the chain reaction involved in autoxidation of fats. All of the end products of oxidation are formed through the conversion of peroxides. During the initial stages of oxidation, peroxides are formed faster than they are converted, but in the later stages the situation is reversed. Thus, a typical curve showing peroxide number as a function of time will begin at a low value, increase to a maximum, and then decrease again as the degree of oxidation proceeds. Peroxide numbers are expressed as mlliequivalents of peroxide per kilogram of sample. Either a higher or lower peroxide number value may be indicative of a quality change, but lower values would not be obtained until the very advanced stages of oxidation.

Thiobarbituric acid (TBA) value is used to measure the end products of oxidation. This test is not as widely used as some others but is more sensitive (Williams 1966). Thiobarbituric acid reacts with the end products of the oxidation of linolenic acid, and the concentration of these products is represented by the TBA value. Unlike peroxide number, TBA value always increases as oxidation proceeds. These two indices are used together to determine if oxidation is in the beginning or the more advanced stages.

EXPERIMENTAL PROCEDURE

An evaluation of soybean oil quality was made from samples of beans used in the drying experiments previously reported by Overhults et al. (1973). Equipment and procedures pertaining to the drying aspect were described by these investigators and only those procedures which relate to oil quality are repeated here.

Soybeans of the Cutler variety were hand harvested and shelled at naturally occurring moisture contents of 20, 23, and 33 percent.* Control samples were harvested after the beans had dried in the field to a 10 percent moisture level. Freshly harvested samples of beans were placed in plastic bags, flushed with nitrogen to remove as much oxygen as possible, and stored at -20 F for approximately 6 weeks before the drying tests were performed. Although not experimen-

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*All moisture contents are reported as percent wet basis.

tally verified, this storage temperature and period was assumed to have a negligible effect on the test results. All experimental samples were thawed at room temperature before being dried to a moisture content of 10 percent. Drying air temperatures of 100, 160 and 220 F were utilized. The control samples were treated in the same manner as the other experimental samples except that they were not exposed to any heated air drying.

Samples of oil were extracted from beans having each of the three initial moisture levels and having been dried at temperatures of 100, 160, and 220 F. An oil sample was also taken from the control beans. The extraction procedure was a partial extraction method which recovered approximately 50 to 60 percent of the total oil in the beans. Six hundred grams of dried soybeans were ground through a no. 10 mesh screen in a Wiley mill and mixed with diethyl ether in a Waring blender. The oil-solvent mixture was filtered twice, after which the ether was evaporated under a partial vacuum. A small amount of heat was supplied from a hot water bath but temperatures were always less than 100 F. Prepared oil samples were placed in non-transparent polyethylene bottles, flushed with nitrogen, and stored in the dark at room temperature.

Quality tests were performed according to established methods of analysis. Each test was replicated three times. Free fatty acid content, peroxide number, and iodine number were determined using AOAC (1970) standard methods of analysis. Procedures for thiobarbituric acid are empirical. Sidwell et al. (1954) evaluated the use of thiobarbituric acid as a measure of fat oxidation and concluded that the test could be used successfully to follow the oxidation of soybean oil. The procedure described by these investigators was used (with the exception of one additional step) to determine the TBA values reported in this experiment. Because of the cloudiness of the oil samples, it was necessary to wash the TBA reagent-oil mixture with approximately 10 ml of petroleum ether after removal from the boiling water bath. This step resulted in a clear sample which was suitable for spectrophotometric analysis.

TABLE 1. COMPARISON BETWEEN EXPERIMENTAL AND CONTROL MEANS OF QUALITY INDICES*

A. Free Fatty Acid Content (% Oleic)

Moisture content, percent wb	Drying temperature, deg F 100	160	220
20	0.16	0.30**	0.27**
23	0.18	0.36**	0.30**
33	0.32**	0.36**	0.45**
CONTROL MEAN = 0.17			

B. Peroxide Number (meq/kg)

Moisture content, percent wb	Drying temperature, deg F 100	160	220
20	0.47	8.80**	0.76
23	0.95	9.00**	1.12
33	1.90	4.94**	3.70**
CONTROL MEAN = 0.69			

C. Iodine Number (g/100g)

Moisture content, percent wb	Drying temperature, deg F 100	160	220
20	132.04	130.95	129.93
23	133.95	129.69	129.55
33	130.98	129.48	128.97
CONTROL MEAN = 131.48			

D. Thiobarbituric Acid Value (As x 100)

Moisture content, percent wb	Drying temperature, deg F 100	160	220
20	2.63	7.46**	7.49**
23	2.96	8.20**	7.28**
33	4.27	7.69**	11.20**
CONTROL MEAN = 3.80			

*Numbers in the tables are the mean of three replications. A double asterisk indicates that the experimental mean is significantly different from the control mean at the 1 percent level by Dunnett's procedure (Steel and Torrie 1960).

ANALYSIS OF RESULTS

Data from the experiments described above were analyzed by performing an analysis of variance and by comparing means of the experimental samples to the control means for each of the four quality indices.

Results from the analyses of variance indicated that the influence of temperature on all of the quality indices was significant at the 1 percent level. Initial moisture content was found to affect free fatty acid content and TBA number at the 1 percent level of significance and iodine numbers at the 5 percent level. Peroxide number of the oil was not significantly affected by initial moisture content of the beans.

Comparisons between experimental and control means for the four quality indices are presented in Table 1. Dunnett's procedure as described by Steel and Torrie (1960) was used for making these comparisons. This test is similar to a least significant difference technique except that it is designed specifically for testing a number of treatment means against a single control mean. Thus the experimental means in Table 1 are compared only with the control mean and not with each other.

Oil extracted from beans having the highest initial moisture content and those dried at the two highest temperature showed a significant increase in the amount of free fatty acids present. Peroxide numbers increased significantly in all samples dried at 160 F and also in the high-moisture beans dried at 220 F. Iodine number of the experimental samples was not significantly different from that of the control sample for any of the conditions tested. TBA values increased significantly in all samples dried at 160 and 220 F.

Comparison of these results with grading criteria used in the soybean oil trade and other reported criteria indicates that although some oxidation has occurred, the overall quality of the oil may have decreased only slightly. All free fatty acid contents were well below the 0.75 percent maximum allowed in crude oil by the National Soybean Processors Association (1971). Iodine numbers are often reported in the range of 127 to 138. The NSPA has established a maximum peroxide number of 2.0 meq/kg for fully refined soybean oil. No specific standard is quoted for crude oil, but the criteria used in grading crude oil is usually much less stringent than that used for refined oil. No maximum TBA value has been established with which these results could be compared. Sidwell et al. (1954) reported TBA values of highly oxidized soybean oil in the 100 to 120 range or approximately 10 times the maximum value for any test in this experiment.

Both temperature and moisture content seemed to affect the results, but temperature was the more predominant of the two. Figs. 1-4 show the effect of temperature on each of the quality indices. While not entirely consistent in all cases, several general

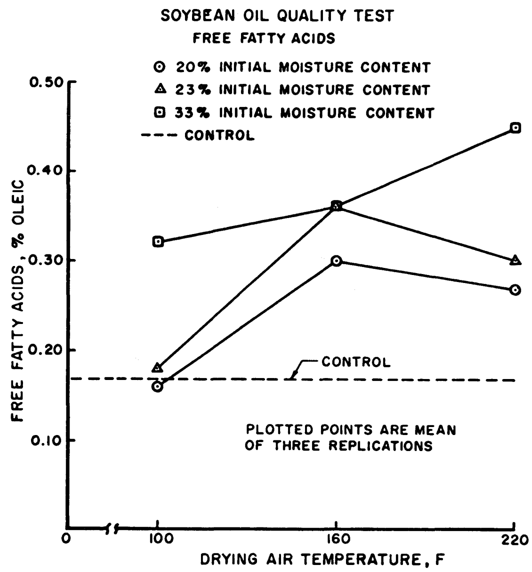

FIG. 1 Effect of temperature on free fatty acid content.

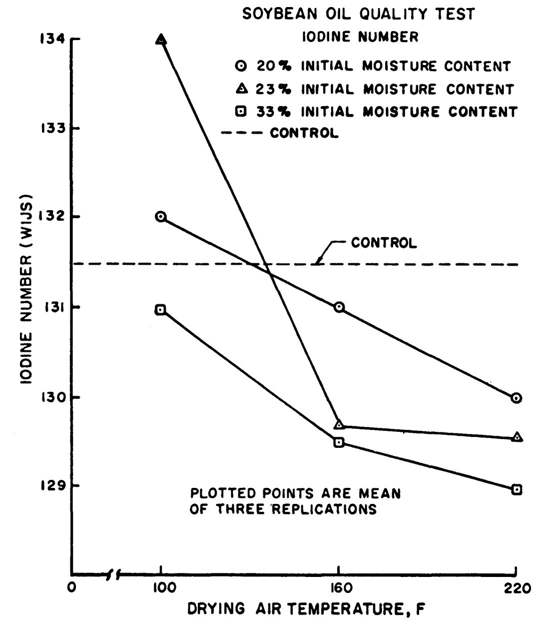

FIG. 2 Effect of temperature on iodine number.

trends are present. Free fatty acid content and TBA value increase while iodine number decreases as the drying air temperature was increased. The peroxide number exhibits a pattern similar to a normal peroxide curve which increases to a maximum and then decreases as the degree of oxidation progresses.

Although no attempt was made to determine total oil content, all extractions were performed in the same manner and on the same sample size of beans. Upon weighing the extracted oil it was noted that approximately 70, 80, and 90 g of oil were consistently obtained from beans dried at 100, 160 and 220 F respectively. No noticeable difference in oil yield was observed for samples of different initial moisture contents.

SUMMARY AND CONCLUSIONS

Soybeans having three different initial moisture levels were dried at three temperatures. Oil was extracted from each sample and its quality compared with that of a control sample. Free fatty acid content, iodine number, peroxide number, and TBA value were used as indices to evaluate oil quality. Oxygen was excluded from contact with the beans and oil except during the drying process so that the results represent the effect of drying on oil quality.

The results indicate that some oxidation of the oil occurred but that the overall quality was not seriously affected. However, because some oxidative deterioration was incurred, the storage life of the beans may well have been decreased substantially.

Both temperature and initial moisture content were found to have a significant effect on the various quality indices. The temperature effect is not unexpected in view of the basic fact that increased temperature speeds the rate of chemical reactions. The amount of moisture present may also affect the reaction rate, but it

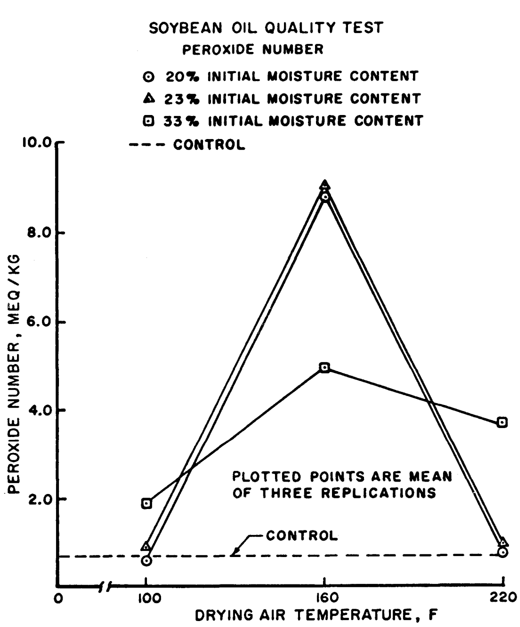

FIG. 3 Effect of temperature on peroxide number.

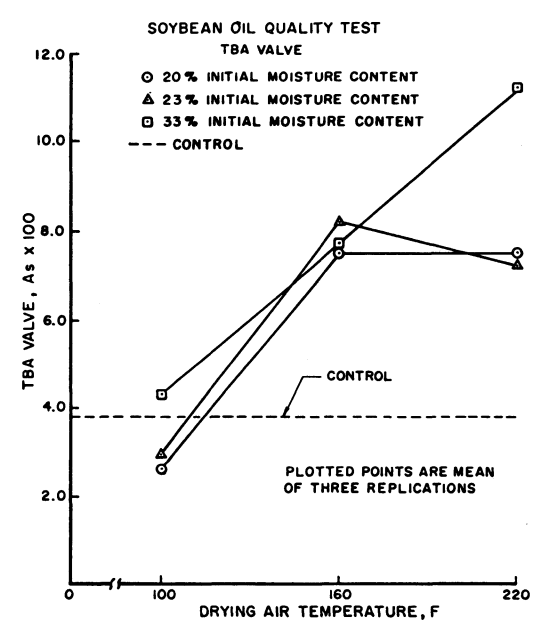

FIG. 4 Effect of temperature on thiobarbituric acid value.

should also be noted that initial moisture content influences the time required for drying. Therefore, it is likely that the initial moisture effect is really a reflection of the time the oil was exposed to a given temperature. The iodine number was not very useful in evaluating oil quality since it did not change significantly for any condition tested.

Some internal deterioration of the bean was indicated by the greater oil yield of beans dried at higher temperatures. While it would be a desirable effect to make the oil more readily extractable, any breakdown in the physical structure of the beans would also contribute to a decreased storage life for the dried product.

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