Effect of Moisture and Temperature on the Phosphorus Content of Crude Soybean Oil Extracted from Fine Flour

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Analysis of total oil content in soybeans is usually done by extracting flours, whereas commercial extraction for recovery of oil is done by extracting flakes. It has recently become apparent that phosphorus content of crude soybean oil extracted from flours can vary depending on extraction temperature and flour moisture. In this study, flour moistures below 6% yielded crude oil with low phosphorus (15 ppm), but phosphorus in the oil increased rapidly to 260 ppm at 9% moisture. When temperature of the extraction was increased from 25 to 60°C, the phosphorus in extracted oil also increased for moisture contents of 6.6% and 8.3%, but not for moisture contents of 5% and 3%. In addition to the effects of extraction temperature, it was found that preheating whole soybeans at various temperatures affected phosphorus in oil from extracted flour. Preheating at 130°C caused high phosphorus content regardless of how dry the flour was, whereas preheating at 100°C or below caused phosphorus content that increased with increased moisture. The response of phosphorus content in crude oil to temperature and moisture may be useful in improving the quality of commercially extracted soy oil.

KEY WORDS: **Crude soy oil phosphorus, fine soy flour, soy oil extraction, temperature and moisture.**

When soybeans are extracted for analysis of total oil, they are usually ground rather than flaked. As the moisture content of the ground flour increases, the amount of total oil extracted and the phosphorus content of the oil increase (1,2). The fineness of the ground flour also influences the amount of oil extracted, as well as the rate of extraction (3).

Clark and Snyder (4) noted that increases in the temperature of extraction, as well as in the temperature of pretreatment of the soybeans, increased the amount of phosphorus extracted in the crude oil. Recently, the possibility was considered of applying this knowledge about analytical extractions to commercial extractions (5,6). Pilot plant-scale extractions of fine flours yielded crude oils with phosphorus contents of 15–30 ppm, about 1/10 of the normal phosphorus content for commercial extraction of flakes.

To better understand the effects of temperature and moisture on phosphorus content of crude oil and on total oil extracted, a series of extractions of fine full-fat flours was done. The results are reported here.

MATERIALS AND METHODS

Dehulled "Forrest" soybeans were ground in a Udy cyclone sample mill (UDY Corp., Fort Collins, CO) and sieved with an Alpine Air-jet sieve (Alpine American Corp., Natick, MA) through a 100-mesh screen.

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In moisture studies [analysis by AOCS method Ac 3-44 (7)] flours above 6% moisture were obtained by equilibrating whole soybeans in a desiccator over water to a moisture higher than needed, because moisture is lost during grinding and sieving when making 100-mesh flour. Low-moisture flours were obtained by grinding and sieving in humidities of 35% and less, or equilibrating whole beans over a desiccant in a closed container to the desired moisture level.

The AOCS official method Ac 3-44 (7) was followed for the Goldfisch extractions, with the following adjustments: soybeans were not preheated except in the study where preheating temperatures were investigated, soybeans were dehulled, and 100-mesh flour was analyzed.

The rapid-equilibrium extractions (4) were done for 30 min, which compare well in total oil with 5-hr Goldfisch extractions. Extraction temperatures above 25°C were maintained by using water baths at the desired temperatures.

Phospholipids were determined by wet ashing a known amount of oil and analyzing for phosphorus by the Bartlett method (8).

RESULTS AND DISCUSSION

The results in Figure 1 show how moisture content of a 100-mesh soybean flour is related to phosphorus content of the extracted oil. The extraction method was Goldfisch, so the temperature of the actual extraction was not known. The solvent was petroleum ether, and its boiling point was 42°C. The results show that moisture content had a dramatic effect on the amount of phosphorus in the extracted oil. Little phosphorus was extracted with moistures below 7%, but from 7.5% to 9% moisture, the phosphorus extracted increased rapidly.

We have experimented with lowering the moisture content of soybean flakes (0.010 inches in thickness prepared commercially) to 5% and extracting crude oil. For flakes, phosphorus content did not decrease with moisture decrease (data not shown).

It is difficult to control the temperature of the Goldfisch extraction unless the solvent is changed, as was done earlier (4). To keep the same solvent while varying moisture, we used the rapid equilibrium method (3) with a 30-min extraction time. The results in Figure 2 show that, for 3% and 5% moisture, temperatures of extraction ranging from 25 to 60°C had little effect on phosphorus extracted. However, as the moisture increased (6.6% and 8.3%), the higher the temperature, the more phosphorus was extracted.

Not only did the temperature of extraction have an effect on phosphorus extracted, but temperatures of pretreatment of the soybeans also had an effect. Figure 3 shows data for phosphorus extracted by a 5-hr Goldfisch procedure of fine flour obtained from whole soybeans exposed to various temperatures for 1 hr. For temperatures of 100°C or lower, the general relationship of more phosphorus extracted for higher moistures seemed to

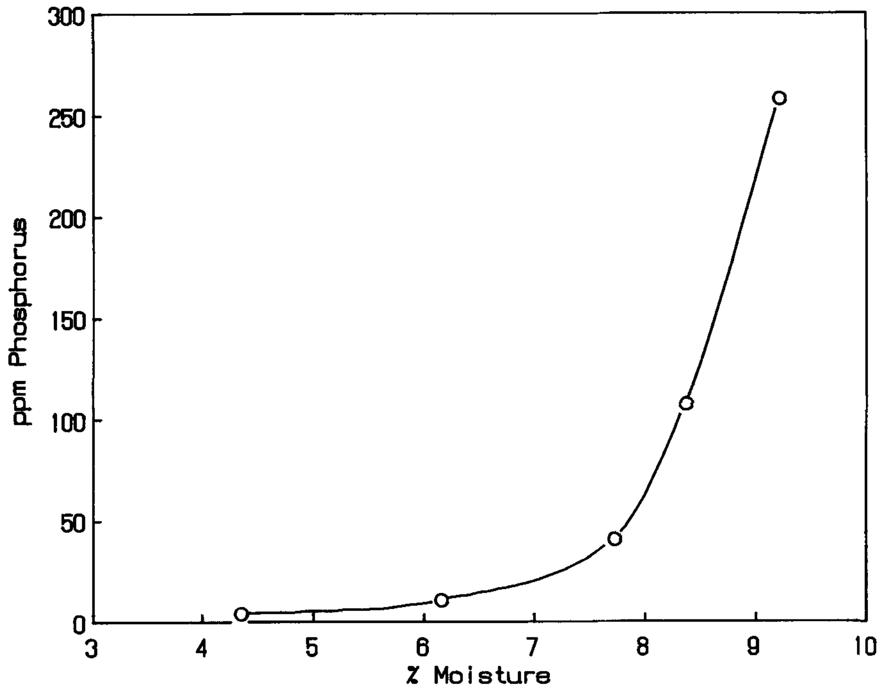

FIG. 1. Change in phosphorus of crude soybean oil as moisture content of the soybean flour is changed. The extraction of soybean oil was by a 5-hr Goldfisch procedure.

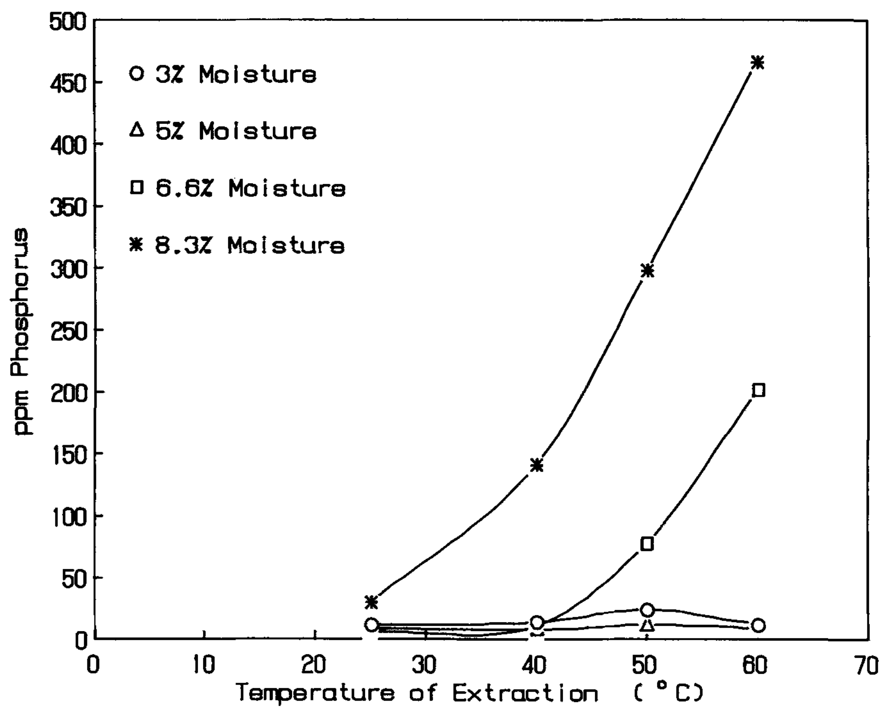

FIG. 2. Change of phosphorus of crude soybean oil as moisture content and extraction temperature are changed. The extraction of soybean oil was by a 30-min equilibrium procedure.

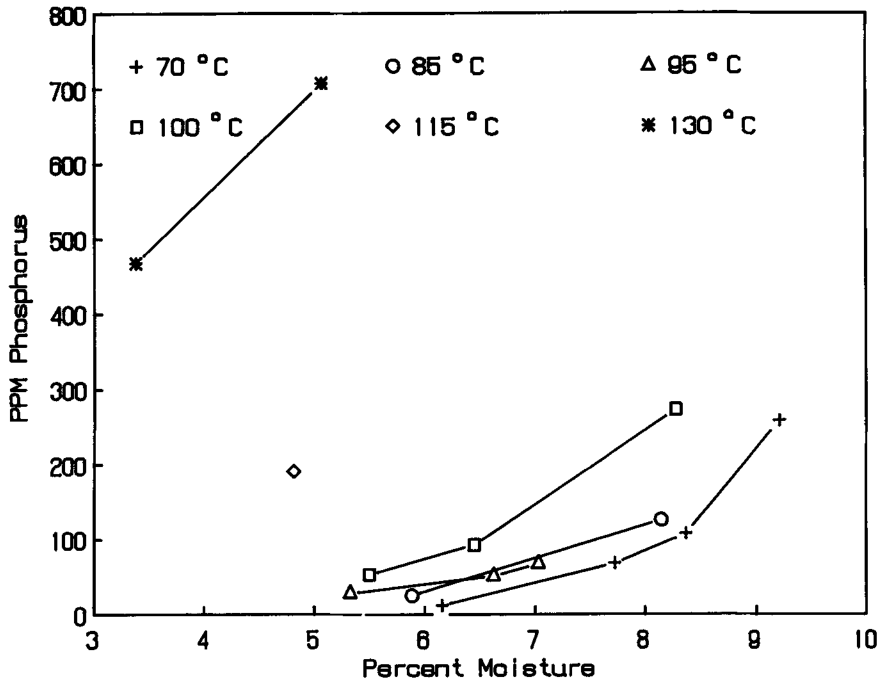

FIG. 3. Change in phosphorus of crude soybean oil as temperature of pretreatment of soybeans is varied. The temperatures were maintained for 1 hr, and the extraction of fine soybean flour was by a 5-hr Goldfisch procedure.

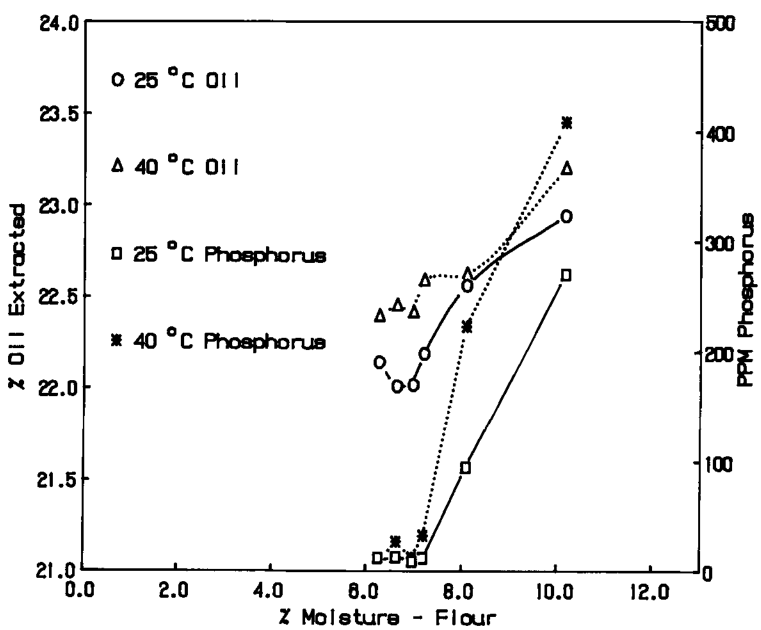

FIG. 4. Changed in total oil content and in phosphorus due to moisture changes. The extraction of fine soybean flour was done at 25°C and 40°C by a 30-min equilibrium procedure.

hold, and relatively little phosphorus was extracted at 5–5.5% moisture. Also, the lower the pretreatment temperature, the less phosphorus was extracted. However, for pretreatment temperatures above 100°C (115 and 130°C), considerable phosphorus was extracted, even at low moisture content.

There are indications in the literature (1,2) that phosphorus extraction is increased by higher moisture, and also that total oil extraction increases with moisture. Figure 4 shows data for total oil and phosphorus extraction at 25 and 40°C. The 30-min rapid-equilibrium method was used, and the data show that at both temperatures phosphorus and total oil increased with increasing moisture. Furthermore, the increased phosphorus could not account completely for the increase in total oil. The increase in total oil at 40°C was 0.7%, and the phospholipid increase (30 × 400 ppm P or 1.2% on an oil basis) could account for only about 0.2% of that increase (the oil being about 1/5 the total weight of the soybean). For extraction at 25°C, the total oil increase due to moisture change was about 0.9%, and the increase in phospholipid (calculated as above) was about 0.16%.

The effect of moisture on phosphorus extraction may be related to the report that phospholipids exist in crude soybean oil as reverse micelles (9). That is, the polar portion of the phospholipid is towards the interior of the micelle along with water, and fatty acid hydrocarbon chains are directed outward towards the triglyceride. Perhaps at less than a certain water content, insufficient water exists for the formation of reverse micelles and, consequently, phospholipids remain as membrane structures and are not soluble in the hexane miscella.

The effect of temperature most likely is due to increased solubility of the phospholipid at higher temperatures. This would account for the increasing amounts of phosphorus extracted at higher extraction temperatures. Also, the increased phosphorus extracted with increasing pretreatment temperatures could be due to increased solubility of phospholipids in the hot triglyceride.

The fact that crude soybean oil can be extracted with variable phospholipid content depending on extraction conditions means that phospholipid may not already be dissolved in the oil before extraction. Thus, control of extraction conditions could be a major factor in the control of crude soy oil quality.

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