Soy Hull Carbon as an Adsorbent of Minor Crude Soy Oil Components

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ABSTRACT: A carbon adsorbent was prepared from soy hulls. The adsorbent was used in a laboratory study to examine its performance under commercial soy oil adsorption bleaching conditions. Phospholipids, peroxides, and free fatty acids were effectively removed from the soy oil with little effect on carotenoid content. There may be competitive adsorption between oil components, the rank of the affinity of oil components for soy carbon was phospholipid > peroxides > free fatty acid > lutein. *JAOCS 73,* 527–529 (1996).

KEY WORDS: Adsorption, free fatty acid, peroxides, phospholipid, lutein.

Commercial bleaching of soy oil is important in obtaining a product that is acceptable to consumers and in removing the residues of previous refining steps. Bleaching is achieved by adsorption of oil pigments onto bleaching clay at 100°C under reduced pressure (1). The major pigment removed is the xanthophyll lutein. Residual free fatty acids (FFA), phospholipids (PL), and peroxide oxidation products, remaining after alkali-refining and the degumming process, are also adsorbed. Bleaching clay is modified montmorillonite clay, whose performance is often enhanced by acid activation.

There is interest in examining alternatives to conventional bleaching clay. In Nigeria, the bleaching effectiveness of local Nsu and Okija clays were examined because montmorillonite clays were unavailable (2). Rice hull silica has also been examined as an alternative adsorbent in vegetable oil processing (3). Rice hulls are readily available in many developing countries and are a major co-product and waste material of the U.S. rice industry. Soy hulls are also an important co-product and are utilized mostly as a fiber source in animal feeds (4). This study investigates the production of carbon from soy hulls to create a novel soy product.

Carbon is infrequently used in commercial oil processing, but it has been effective in increasing bleached oil stability when used with bleaching clay (5), and it adsorbs chlorophyll (6). More recently, carbon has been used to process miscellas of sesame oil (7) and squash seed oil (8) to adsorb pigments and oxidation products.

The objectives of the study were to prepare carbon from soy hulls and examine its ability to adsorb PL, peroxides (POD), FFA, and lutein from soy oil in the laboratory, under conventional industrial soy oil bleaching conditions.

MATERIALS AND METHODS

Oil and adsorbent source. Crude soy oil and soybeans were donated by Riceland Foods (Stuttgart, AR).

Carbon preparation. One kilogram of soybeans was dehulled in a blender, and the hulls were recovered by aspiration. The soy hull fragments were heated in a muffle furnace to 400°C. The residue was comprised of small pieces of carbon, which were placed in a desiccator to cool.

Bleaching. One hundred grams of oil was stirred with a magnetic stir bar and heated at 100°C under 2 mm Hg pressure for 30 min with variable amounts of carbon adsorbent (3). Each determination was repeated. The oil was decanted from the carbon fragments. Lutein (9), POD value (10), PL phosphorus (11), and FFA (12) were measured before and after adsorption. Adsorbent dose was plotted against residual concentration of each component assayed.

RESULTS AND DISCUSSION

Approximately 102 g of hulls was obtained from a kg of soybeans. This amount of hulls provided 16.5 g of carbon.

Figure 1 shows the residual lutein remaining after exposure to variable amounts of soy carbon. There was little reduction in lutein concentration with the adsorbent doses used. This confirms earlier findings that carbon is not typically a good carotenoid adsorbent (6). The abnormality in the data at 5 g of adsorbent could be because the experimental adsorbent is probably heterogeneous, and carbon masses of equal weight may not have equal surface areas or the same number of adsorption sites per unit surface area.

Adsorption of FFA onto the soy carbon is shown in Figure 2. Doses less than 3 g were not very effective. However, doses greater than 3 g produced an appreciable reduction in FFA concentration.

Figure 3 shows the adsorption of POD as indicated by the reduction in POD value after exposure to soy carbon. One or 2 g of adsorbent was effective in reducing POD

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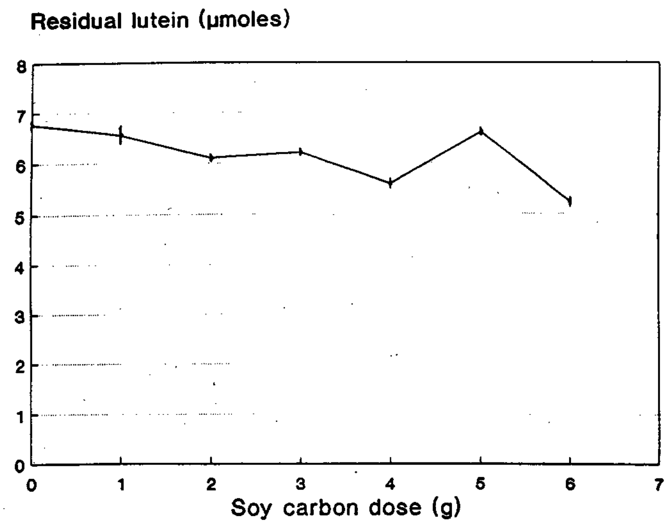

FIG. 1. Residual lutein in 100 mL of crude soy oil after mixing with various amounts of soy hull carbon at 100°C under reduced pressure for 30 min. Determinations were made in duplicate. Range is shown by a bar.

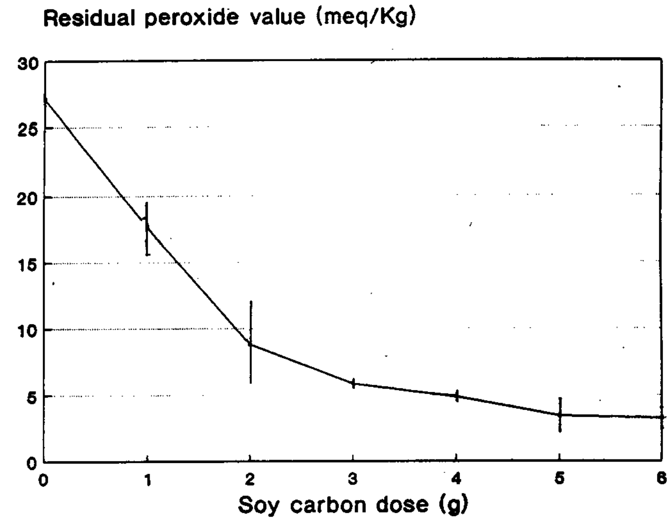

FIG. 3. Residual peroxide value in 100 mL of crude soy oil after mixing with various amounts of soy hull carbon at 100°C under reduced pressure for 30 min. Determinations were made in duplicate. Range is shown by a bar.

values, with little enhanced adsorption on addition of further adsorbent.

Residual PL phosphorus after adsorption is shown in Figure 4. The lowest dose produced a considerable reduction in phosphorus levels, and increasing the dose did not greatly enhance adsorption. Nevertheless, there was additional phosphorus adsorbed on adding more carbon. The abnormal data point obtained with 2 g of carbon may be due to heterogenous surface properties as discussed in relation to Figure 1.

Most phospholipid was adsorbed by 1 g of adsorbent with limited adsorption of other components that were measured. Most of the POD was bound by 2 g of carbon. In contrast, there was little FFA adsorbed until the adsorbent dose exceeded 3 g, and only minor pigment reduction was observed throughout. There may be competitive adsorption when adsorbent is limited (9). The affinity of the oil components for soy carbon appears to be PL > POD > FFA > lutein. A previous adsorption study with sesame oil miscellas reported that FFA adsorption was more dependent on carbon adsorbent concentration than POD adsorption was (7), a result which was also found in this study.

Carbon surfaces have been considered to be disordered graphite sheets, which adsorb by Van der Waals forces (13). However, carboxyl, carbonyl, lactone, pyrone and phenol

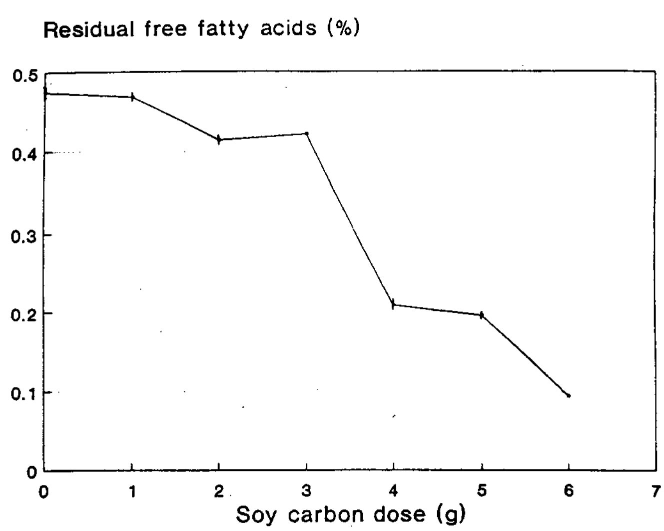

FIG. 2. Residual free fatty acid in 100 mL of crude soy oil after mixing with various amounts of soy hull carbon at 100°C under reduced pressure for 30 min. Determinations were made in duplicate. Range is shown by a bar.

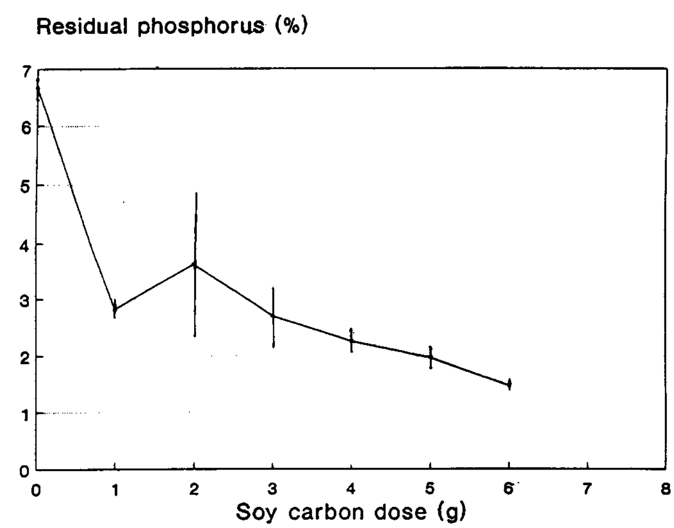

FIG. 4. Residual phospholipid phosphorus in 100 mL of crude soy oil after mixing with various amounts of soy hull carbon at 100°C under reduced pressure for 30 min. Determinations were made in duplicate. Range is shown by a bar.

groups are commonly found on the surface of amorphous carbon (14). Such functional groups may be responsible for surface polarity and may explain the relative affinities of the soy oil components for the adsorbent. PL is the most ionic species measured, whereas POD and fatty acids are polar and may bind by hydrogen bonding. Minyu and Proctor (14) proposed that a molecule's ability to compete for a polar surface was based on its ability to hydrogen bond, rather than on its polarity. This is supported by the data in this study.

In summary, carbon derived from soy hulls was found to adsorb several soy oil components that need to be removed from crude soy oil, including POD and FFA, which are traditionally removed by acid-activated clays. Because the carbon has little capacity for soy oil pigments, it would probably be best used with bleaching clay or as a pretreatment material. Furthermore, there is a loss in adsorption efficiency with larger doses. This indicates that moderate adsorbate doses can produce an oil quality very similar to that obtained with larger carbon weights.

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