Safflower Meal[1]

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Abstract

Safflower meal from undecorticated commercial seed is useful feed for ruminant animals. Its low energy content is a problem in poultry and swine rations.

Partially decorticated meals are valuable for ruminants and are also quite suitable in poultry rations if provision is made for extra metabolizable calories, and if other feed ingredients supply additional lysine and methionine. In a properly balanced ration safflower meal produces growth rates superior to those from optimally supplemented soybean oilmeal.

The flour obtained by essentially complete removal of oil and hulls is light colored, bitter, and contains about 60% protein. Debittering yields a relatively bland, 70% protein flour which has potential as a human food.

Introduction

THE MAJOR EDIBLE OILS of the US are by-products. If there were no need for starch, there would be no corn oil produced. If there were no need for cotton fiber, there would be no cottonseed oil produced. Even in the case of soybeans, dollar returns from the meal passed up returns from the oil some years ago. Safflower oil competes to some extent with these oils for markets, but it is the primary product of the processor who derives less than 15% of his gross returns from nonoil by-products. As a result, fluctuations in the prices of competitive oils have a disproportionate effect on the economics of growing and processing safflower seed (1). Improving the returns from the meal would tend to stabilize the safflower industry by reducing effects of oil price fluctuations as well as bringing greater overall returns from the crop to the processor and the farmer.

The objectives of this paper are to describe the chemical, physical, and nutritional properties of the meal products available or potentially available from commercial or promising experimental varieties of safflower seed and to report some progress in our laboratory toward increasing the value of the meal.

Undecorticated Safflower Meal

The seeds of commercial varieties of safflower consist of about 60–65% kernel and about 35–40% hull. The seed contains 36–40% oil. When the bulk of the oil is removed by extraction or pressing, the oilseed cake contains about 20–22% protein. Such cake is about 60% hull. Since the hull is about 70% holocellulose, 21% lignin, and 1% ash little of it is usable by poultry. Even ruminant animals, which have a built-in cellulose digestion vat, the rumen, would be expected to have a difficult time with safflower hulls since it is known that even the 5–10% lignin in alfalfa products markedly hinders digestion of alfalfa cellulose and pentosans. Research on feeding high levels of safflower hulls to cattle has shown that this is indeed the case. Safflower hulls contain only about 15–27% total digestible nutrients and their incorporation (2) in a ration reduces feed efficiency (3,4). However, growth is not impaired when adequate energy and protein are supplied from some other source. A practical development has been the use of hulls to provide bulk in high grain rations for beef cattle.

Since the oilseed meal from undecorticated seeds contains about 60% hull, it is considerably lower in total digestible nutrients than other oilseed meals with which it has to compete for a market in animal rations. Feeding experiments have been carried out to determine the nutritional value of expeller or extracted undecorticated meals (18–24% protein) for calves (5–7), steers (6,8–14), dairy cows (15), lambs (6), and swine (16,17). The results have shown that the meal is palatable and can be used in ruminant rations as a protein source in place of soy, cottonseed, or linseed meals, if used on an equal protein basis and if adequate energy is supplied. As would be expected, efficiency of feed conversion is reduced because lignin interferes with cellulose digestion as discussed above. As the safflower industry expands, it will be necessary to ship the meal further to reach markets, and freight costs on the hull in feed are as great as on the nutritionally rich component. Further, opening the new and higher-priced poultry rations market would increase returns. Such markets are now closed to a product as high in fiber as undecorticated safflower meal.

Partially Decorticated Safflower Meal

It is thus apparent that the primary problem in upgrading safflower meal is reduction in the hull content. Two current approaches to this problem are: a) reduction of natural hull content through plant breeding and b) physical separation of the hulls from the kernel. Excellent progress has been made in development of thin-hulled seed (18,19) by plant breeders in state experiment stations, in USDA stations, and in private industry. Several types of thin-hulled seeds have been produced experimentally with 18–22% hull as compared with 35–40% in commercial types. These new varieties are expected to become commercially available in the next several years and will produce more protein and oil per acre than present seeds. We conclude from our analyses of some two dozen new thin-hulled and commercial seeds that the compositions of the oil and kernel are not appreciably altered in the thin-hulled types. The hulls of the thin-hulled seeds are higher in protein and lower in fiber than the usual hulls but still contain about 20% lignin. These thin-hulled types will greatly affect the economics of safflower production, we believe, and will yield better undecorticated meal for ruminant feeding (e.g., protein content of 35–40%). However they will still contain too much indigestible material for poultry feeds and will, we believe, need to be decorticated for this use.

The second approach to fiber reduction is by decortication, or mechanical dehulling of the seed. The hulls are extremely hard, and the kernels with their 60–70% oil are extremely soft. This combination makes it difficult to avoid losses of oil into the hull fraction during decortication. However, a partially decorticated meal is now commercially available with a guaranteed protein content of 42%. To reach this protein level about two thirds of the hull is removed. The fiber content of this product still seems fairly high (e.g., 14–16%) for high-energy poultry rations, but, as will be pointed out later, the effects on feed

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efficiency are less than would be expected. Nonetheless, a more complete decortication would be desirable if it could be accomplished at low cost.

Considerable research has been done on the nutritional value of experimentally produced partially decorticated safflower meals ranging from 35–48% protein and, more recently, on the commercial 42–45% protein meal. Such work includes feeding trials on chicks (20–25), laying hens (22,23,26,27), lambs (28), and cattle (6,14). The research with chicks showed that safflower protein is primarily deficient in lysine (21). Earlier work indicated that it was also grossly deficient in methionine (21), but more recent results in our laboratory (29) and at Purdue University (24) indicate that safflower meal is higher in methionine and cystine than previously suspected and any methionine deficiency on high safflower rations will be borderline. In any case, at least 25–50% of the supplementary protein in the ration can be supplied by safflower protein if the remaining protein source supplies the needed lysine and methionine. Again no evidence of toxicity or other negative effects was noted except for reduced feed efficiency attributed to the relatively low metabolizable energy in the partially decorticated meal (25).

Since safflower meal is quite well-balanced in amino acids except for lysine and possibly methionine, we felt that it might provide the basis for a good bioassay technique for available lysine in foods and feeds. A typical dose-response curve to lysine on safflower-glucose or safflower-corn rations supplemented with methionine is shown in Figure 1. The assay method has been developed and is in routine use (30). An important extra observation is that safflower meal produces significantly more growth than the corn-soy-methionine control rations. Many lots of soybean meal have been tested under varying conditions with and without supplementary amino acids in addition to methionine, but the safflower meal consistently produces better gains. Figure 2 shows the results of two such experiments where the comparisons were made at two levels of dietary protein. The safflower advantage makes the 18% protein safflower rations equal in growth response to the 22% soybean meal ration. Because of the low energy-value feed, efficiences of safflower-fed groups in experiment 1 (Fig. 2) were lower than those of soybean-meal-fed groups. In experiment 2 the rations were made isocaloric, so that the feed efficiencies on soy and safflower rations were not significantly different at equivalent protein levels.

Safflower Meal as Human Food

If the hull of safflower were removed quantitatively, as by dissection, the 600 lb of kernel obtained from a

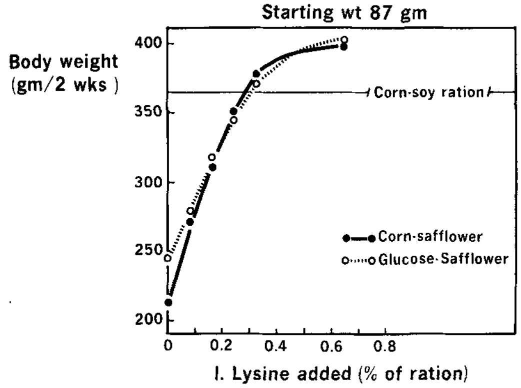

FIG. 1. Dose-response curves for chicks for lysine supplementation of safflower-meal-based rations.

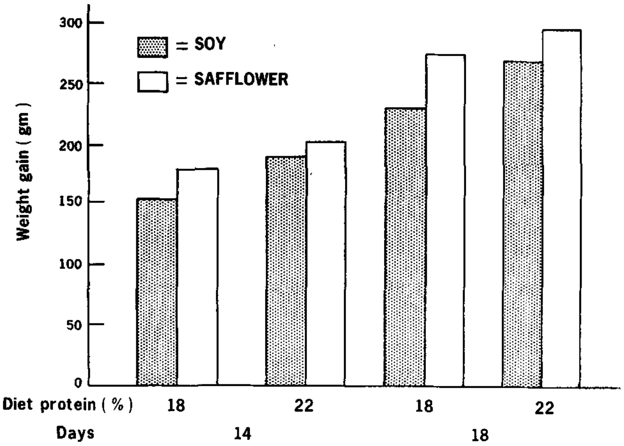

FIG. 2. Comparison of weight gains of chicks fed safflower or soybean oil meal as the main source of protein.

1000 lb of seed would yield about 360 lb of oil and 240 lb of safflower flour containing about 156 lb (or about 60%) of protein. The crude fiber of such material is about 4% and thus it can be used as a human food.

In order to evaluate the suitability of safflower protein for food use, we have studied safflower kernel from a new thin-hulled type of seed (29,30). This material is undistinguishable in composition from the kernel of the present commercial varieties and indeed from the kernel of the high oleic acid variety being developed at the University of California (31). The thin-hulled seed can be decortictaed by a mechanical laboratory procedure we have developed to produce safflower kernel flour. Analysis of the separated products is shown in Table I. Further improvements in the laboratory separation process are possible since the pure kernel obtained by dissection contains about 2.5% fiber and about 65% protein.

The essential amino acid content of safflower protein is compared in Table II with human requirements as given in FAO-WHO Recommended Provisional Amino Acid Pattern (32) and with an adjusted pattern based on recent reevaluations of human requirements (29). The composition of soybean and cottonseed proteins is also included for comparison. Only lysine is critically limiting in safflower while methionine and isoleucine are borderline. In the case of soy protein, only methionine is limiting and a surplus of lysine is present. Cottonseed similarly is low only in methionine when the adjusted pattern is considered, but it contains nor surplus of lysine. Combining 40 parts soy flour with 60 parts safflower flour achieves an optimum balance with the limiting amino acid, lysine, at 92.5% of the standard. This is a very high score for a plant protein blend unsupplemented with animal protein or synthetic amino acids. Other proteins, high in lysine, such as fish or meat, could, of course, similarly supplement safflower protein.

Table III shows a comparison of the same three oilseed proteins in amino acids not in the FAO Pro-

TABLE I
Brown-Striped Thin-Hulled Safflower
Percent on Moisture and Oil-Free-Basis

	Kernels	Hulls
Crude protein	58.8%	8.8%
Ash	9.9	5.0
Lipid (ether extract)	1.0	1.0
Crude fiber	5.7	49.4
Lignin	3.2	24.0
Pentosans	4.9	21.5
Cellulose	2.3	35.0
Soluble carbohydrates, organic acids, etc.	19.9	4.6

TABLE II
Safflower Seed, Soybean, and Cottonseed Proteins Compared with the F.A.O. Provisional Reference Amino Acid Pattern

	Provisional pattern		Safflower kernel			Soybean			Cottonseed		
	g/16 g N		g/16 g N	% of standard		g/16 g N	% of standard		g/16 g N	% of standard	
	orig.[a]	adj.[b]		orig.[a]	adj.[b]		orig.[a]	adj.[b]		orig.[a]	adj.[b]
Isoleucine	4.2		4.0	95	95	4.8			3.8	91	91
Leucine	4.8		6.2			7.3			5.9		
Lysine	4.2		3.1	74[c]	74	5.8			3.8	90	90
Phenylalanine	2.8		4.4			4.8			5.2		
Tyronsine	2.8		3.1			3.0			2.6		
Total sulfur AA	4.2	3.4	3.3	79	97	2.9	68	85	3.0	72	88
Methionine	2.2	1.7	1.7	78		1.4	64[c]	83[c]	1.4	64[c]	82[c]
Threonine	2.8	3.3	3.3			3.8			3.5		
Tryptophane	1.4	1.1	1.6			1.7			1.2	86	
Valine	4.2	2.8	5.7			5.0			4.9		

[a] Reference No. 33.
[b] Reference No. 29.
[c] Chemical score is % of pattern for first limiting amino acid.

TABLE III
Amino Acids Not in FAO Provisional Reference Amino Acid Pattern

	Safflower	Soybean	Cottonseed
	Amino acid (g/16 g N)		
Histidine	2.4	2.5	2.6
Arginine	9.3	6.9	10.0
Glycine	5.8	4.0	5.3
Aspartic acid	9.8	10.6	10.0
Glutamic acid	19.4	17.6	17.7
Serine	4.4	5.1	4.5
Proline	4.1	5.2	3.6
Alanine	5.8	4.1	4.0
Total (% of protein)	61.0	56.0	57.7

visional Pattern. You will note that safflower contains enough histidine to meet the needs of children (2.4 g/16 g N) (29) and is a rich source of arginine and glycine which are required by chicks.

Note that all the safflower amino acid figures shown in the tables apply to 42% protein meal as well as to the 58% protein flour since the hull component supplies only 3% of the protein in the partially decorticated meal and 3% is the limit of accuracy of our analytical procedure.

Reports on biological evaluation of protein quality with laboratory animals are sparse (29). In Table IV are presented some of our results which show that Protein Efficiency Ratios as measured with rats (29) follow the expected pattern on supplementation with lysine and methionine. Thus there is no evidence of imbalance in the safflower pattern or of deleterious substances in the product.

One difficulty became apparent, however, from the standpoint of the food technologist. Although the safflower kernel flour was very light colored, it tasted bitter. Preliminary experiments showed that practically all of the bitter principle could be extracted with 70% alcohol with less than 5% loss of nitrogen. The extracted product, which contained about 70% protein, had a flavor which was not deemed undesirable by an informal taste panel. Further, preliminary tests showed that meat-like patties containing this 70%-protein safflower flour were quite acceptable to the panel. When the product was added to bread at a 5% level based on the flour, loaf volume was reduced slightly and a characteristic but not unpleasant flavor was noticeable. More extensive tests are in progress.

TABLE IV
The Effects of Supplementation of Safflower Flour with Methionine and Lysine on Protein Efficiency Ratios

	Total S amino acids as % of protein	Total lysine as % of protein	PER
Safflower flour (58% protein)	3.34	3.09	1.39
Same plus methionine	4.20	3.07	1.59
Same plus methionine and lysine	4.20	5.00	2.09

Another approach to human food products is through the preparation of protein isolates. Some work has been done by Van Etten et al. (33) on extraction and recovery of safflower protein. Good recoveries of safflower protein were obtained by procedures similar to those used for preparation of isolates from soybeans and peanuts. No results of studies on functional properties, flavor, or use in foods have been reported.

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