Potential for Detoxified Castor Meal[1]

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ABSTRACT

Castor oil is a useful chemical raw material, but the pomace remaining after its extraction is potentially toxic and allergenic. Improving the economic value of castor pomace will provide considerable incentive for increased production of castor seed in the United States. Processes for detoxifying and deallergenating castor meal have been developed along with means for evaluating these processes. Castor meal may be used as a feed supplement for both ruminant and nonruminant animals.

Castor plants have long been cultivated and harvested for production of oil. Castor oil is unique in that ricinoleic acid comprises roughly 90% of its fatty acids; thus, castor oil can be considered as a technical grade of triricinolein, in which the hydroxyl groups of ricinoleic acid give the oil its properties of high viscosity and unusual chemical reactivity. The oil is an important industrial raw material, being used in lubricating oils, paints and coatings, cosmetics, plastics and other products of commerce (1). Perhaps its most well known use, now a minor one, is its employment as a cathartic.

Almost 170 million pounds of castor oil are now used annually in the United States, most of which is imported. World production of castor seed in 1968 was over 980,000 tons with a slight decline in 1969 (2) and, probably a rise in production again in 1970. Oil content of the castor seed is between 40% and 55% (1). Where it is grown commercially in the United States, dwarf varieties of castor plants allow it to be machine harvested; in the wild state, castor plants may grow to become small trees.

Although castor oil has been an item of commerce for many years, the pomace which remains after oil extraction has presented many problems. It contains 32-36% protein, but is also contains a toxic albumin, ricin (3), some potent allergens (protein polysaccharides) (4) and an alkaloid, ricinine (5). Because of the potential danger of these components, castor meal has been sold largely for use as a fertilizer in areas where slow nitrogen release is desired. Even this use is limited to situations where human exposure is minimal because of the allergic reactions of sensitized individuals. Detoxification and destruction of allergens could raise the value of castor pomace from ca. $32/ton (its fertilizer value) to a considerably higher figure, based on its protein value in animal rations. The goal for use of castor pomace is animal feeds rather than human foods.

DETOXIFICATION-DEALLERGENATION

Ricin is the most potent of the deleterious materials in castor seed, but it is also the most easily detoxified. Very small amounts of ricin are lethal to nonruminant animals. Effects of ingestion may not appear until 10 to 15 hr afterward. Originally it was reported that ricin caused agglutination of red blood cells and had a proteolytic activity. Ishiguro et al. (6) and Waldschmidt-Leitz and Keller (7) reported separation of the toxic principle from proteins causing the other reported effects, although Waller et al. (8) indicate all effects may exist in the same protein. Pure ricin showed a minimum lethal dose for mice in 48 hr of 0.001 μg of ricin nitrogen per gram of body weight. Fortunately, toxic effects, hemagglutinating activity and proteolytic properties are all destroyed by heat and moisture in combination. Although ricin is not readily detoxified when dry, it is made innocuous by heating with steam (9). Introduction of ca. 20% moisture during desolventer toasting has produced detoxified meal at a castor extraction facility in Texas. The extent of detoxification can readily be measured by a mouse assay (6). Since hemagglutination normally accompanies toxicity, deactivation of ricin may also be followed using guinea pig red blood cells in vitro (10).

Many people who live near facilities where castor pomace is handled become sensitized to the dust to such an extent that they show severe respiratory effects. Thus, it is highly desirable to destroy the antigens in castor as soon as the oil is extracted. Work at the Western Regional Labora-

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TABLE I

Essential Amino Acid[1,2] Composition of Castor Pomace, Grains of Amino Acid per 16 g N

Amino acid	Untreated control	Ammonia-treated[3]	Lime-treated[4]	Steam-treated[5]	Soybean meal
Lysine	2.80	2.27	1.91	2.56	5.8
Histidine	2.05	2.02	1.71	1.92	2.5
Arginine	11.34	10.34	7.59	9.71	6.9
Threonine	3.54	3.32	2.06	3.36	3.8
Glycine	4.21	4.05	4.61	4.05	4.0
Valine	6.00	5.54	5.59	5.72	5.0
"Total sulfurs"	4.11	2.58	2.09	3.50	2.9
Isoleucine	4.91	4.68	4.52	4.64	4.8
Leucine	6.38	6.13	6.05	5.98	7.3
"Total aromatics"	6.52	6.18	5.27	5.60	7.8

[1]Required for chick growth.

[2]Tryptophan essential, but not measured.

[3]6N ammonia, 80 C, 45 min.

[4]4% lime, 100 C, 15 min.

[5]10 psig, 60 min.

TABLE II

Incorporation of Hydroxy Fatty Acids Into Eggs and Body Fat of Chickens

Ration, % castor oil	Per cent hydroxy acids in fat of	
	Eggs[a]	Body tissue[b]
0	0.13	0.13
1.0	0.26	0.17
5.0	0.42	2.3

[a]Average values after 16 weeks feeding.

[b]Average values for three birds at 20 weeks.

tory has led to pilot plant processes for deallergenation by steam, lime and ammonia (9,11 and A.C. Mottola, private communication). Evaluation of these processes was carred out using a guinea pig assay for antigen content (12). In this assay guinea pigs are sensitized toward castor by injection of serum from sensitized rabbits. After a blue dye. is injected into the guinea pigs, the animal is challenged by intradermal injection of an extract of the pomace being tested. A blue spot appears on the skin, the size of which is related to the amount of antigen present in the extract. A series of dilutions are used to determine the potency of the extract.

One of a number of effective procedures for lime deallergenation consisted of heating castor pomace with three times its weight of water and 4% of lime at 100 C for 15 min. The meal was then acidified to pH=5 with phosphoric acid and dried. Steam deallergenation may be accomplished at 10 psig for 1 hr with a liquid-solid ratio of 1:2 (13), while good ammonia deactivation may be done during 3/4 hr with 0.25 liquid-solid ratio of 6N ammonia at 80 C. Deallergenization is effective in all three cases, but one must also take into account the nutritive value of the product. Amino acid analysis of castor protein from various treatments is compared to that of soybean meal in Table I. In castor seed cake lysine is severely limiting nutritionally and methionine plus cystine are also at low levels. Lime treatment appears to deplete these amino acids somewhat more than steam and ammonia treatments.

The last material of potential toxicity is the alkaloid, ricinine. Japanese workers have indicated that ricinine inhibits the growth of chicks when castor meal is fed in large amounts (14). Our first task was to find a chemical assay for ricinine. The method developed was based on the fluorescence of ricinine when it is excited by uv light of 308 mμ. Based on intensity of its fluorescence at 363 mμ, ricinine may be determined quantitatively in amounts of less than 1/2 ppm, if interfering substances are not present (15). We have observed castor pomace with as high as 0.4% ricinine content, though 0.3% is a more common value. It is not significantly depleted by steam or lime treatment. Our recent work shows that ricinine is converted to several compounds which fluoresce at wave lengths close to

TABLE III

Effect of Synthetic Ricinine on Broiler Chicks

Ration, % ricinine	Average weight gain at four weeks, g	Average liver weight, g
0.0	474[a]	11.43
0.01	444ab	11.03
0.025	456ab	11.25
0.05	424b	10.46
0.075[1]	331c	9.07

[1]Two chicks died on this ration after three days.

Statistical significance in gains at $\alpha = 0.05$ is denoted by different letters.

ricinine, so that quantitative analysis procedure is affected. It appears that ammonia treatment lowers ricinine content, but we do not yet know how toxic the reaction products are.

FEEDING

After demonstrating that pilot plant scale processes can be used to deallergenate castor meal, it remained to ascertain whether it can be used as a feed component. Critical questions were whether the residual oil and ricinine in detoxified and deallergenated meal affect animal growth and whether there is incorporation of allergenic material, hydroxy fatty acids and ricinine into the body tissues of animals fed castor pomace.

Ricinoleic acid has been shown to be noncathartic when the oil is mixed with food (16). Absorption, assimilation and metabolism of ricinoleic acid and other hydroxy fatty acids have been reported by Watson et al. (17) and by Binder et al. (18). To confirm these reports, laying hens were fed a control ration and two rations in which 1% and 5% castor oil were added. Eggs were collected at two week intervals and tested for fertility, and hatchability. On alternate weeks the content of fatty acids containing hydroxyl functions in the eggs was determined as per cent of total fatty acids. At the end of the experiments some of the chickens were sacrificed and hydroxy fatty acid content of their body lipids was measured. Results are shown in Table II. Mean egg production per hen was not significantly different at any level. Fertility was significantly decreased at the 5% level, but hatchability of eggs was unaffected by castor oil; only traces of hydroxy fatty acids were incorporated into the eggs. There was a significant increase of hydroxy acids in body fat of the chickens fed the diet highest in castor oil. The concentrations of oil fed are far higher than would occur normally from feeding castor meal with residual castor oil. It is interesting to note that large amounts of castor oil have been consumed by humans when cooking oils were adulterated with castor oil in India during times of oil shortage (19).

Investigators at Kyushu University have indicated that ricinine has adverse effects on the growth of young

TABLE IV

Weight Gain and Feed Efficiencyffor Chicks Fed Ammonia-Treated Castor Meal and Ricinine

Ration No.	Supplement	Per cent lysine added	Chick weight gain, g	Feed efficiency gain/feed
1	Corn-soy control	—	687a	0.679a
2	0.01% ricinine	—	666a	0.681a
3	0.02% ricinine	—	673a	0.680a
4	0.04% ricinine	—	674a	0.665ab
5	0.08% ricinine	—	626b	0.683a
6	5% castor meal 0.09	0.09	662a	0.654b
7	10% castor meal	0.18	678a	0.651b
8	20% castor meal	0.35	657ab	0.624c
9	41.85% castor meal	0.74	575c	0.524d

Statistical significance at $\alpha = 0.05$ is denoted by different letters.

TABLE V

Lysine Dose Response in Chicks Receiving Castor Rations

Castor meal, %	Soybean meal, %	Lysine added, %	Total lysine	Chick weight gain, g[1]	Feed efficiency gain/feed
0	33.70	0	1.22	585a	0.706a
18.5	22.81	0	1.05	456c	0.551c
18.5	22.81	0.1	1.15	485bc	0.570bc
18.5	22.81	0.2	1.25	505b	0.595b

[1]Four-week data.

chickens (15). At the University of California, Davis, pure synthetic ricinine was fed to broiler chicks starting at one day of age and continuing until they were four weeks old. Ten chicks were fed, ad lib. a control corn-soy diet and the same diet containing different concentrations of synthetic ricinine prepared according to the method of Schroeter et al. (20). Results (Table III) show that ricinine does retard chick growth at higher levels. Pathological examination of the chick livers showed no abnormalities, but a fluorescent material, probably a metabolite, behaving similarly to ricinine was present in the livers of chicks on the diets highest in ricinine. A more extensive experiment starting with three-day-old chicks is shown in Table IV. Four pens of seven chicks each were fed the diets shown for a four-week period. Ricinine was added at four levels to a basal corn-soy ration containing 24.2% protein and 1450 kcal metabolizable energy per pound, supplemented with methionine. In the last four diets, lysine- and methionine-supplemented ammonia-treated castor pomace replaced an equal weight of the soybean meal maintaining a constant ration protein content of 24.2%. In these isonitrogenous castor rations, total metabolizable energy was decreased due to the difference in energy between castor and soybean meal. The soybean meal contained 47.5% protein and 1050 kcal metabolizable energy per pound. Ammonia-treated castor meal was partially decorticated so that it contained 47.5% protein; its ricinine content was 0.29%. Chick weight gain or feed efficiency values, not sharing the same postscript letters, are significantly different at the 95% confidence level. In the equicaloric rations more than .04% ricinine was needed to depress weight gain, but at any of the levels fed the feed efficiency was not affected. The metabolizable energy of castor meal seems to be appreciably lower than that of soybean meal since the weight gain per unit of feed is decreased in all the castor diets. However, the adverse effect of the ricinine in castor occurs only at high castor levels. Castor meal should thus be limited in the diet of chickens to about 10-15% of the total ration. Probably its best use is in rations for laying hens.

The effect of lysine supplementation on untreated castor meal is shown in Table V. Here, castor has replaced soybean and corn meal to maintain equal protein levels, but not calories. Thus, even when lysine is brought back to the soybean-corn ration level, feed efficiency is somewhat lower because of the energy difference. The lower growth rate on castor is probably due to effects of ricinine.

A number of beef cattle-feeding tests with detoxified castor pomace have been summarized recently (21). The results indicate the following: there is a net energy difference between cottonseed meal and castor seed meal; residual castor oil in the meal can make up the energy difference; there were not toxic effects of castor evident in the carcasses of over 300 animals fed in a number of experiments at different locations; there is even some evidence that the bacterial flora of ruminant animals may detoxify raw castor pomace containing ricinine; cattle showed good weight gains even when incompletely detoxified meal was fed, as long as they were accustomed to the castor pomace gradually; scouring was observed if a level of 0.9 kg/day of castor pomace was fed without an adaptation period; calves were able to accustom themselves to raw castor seeds when the dose was gradually increased. No extensive experiments in this country with dairy cattle fed castor have been reported. Some are currently in progress.

Castor meal will continue to be produced as long as castor oil is a valuable chemical raw material. Enhancement of the value of castor pomace, then, is a desirable objective. This pomace can be detoxified and deallergenated. It can be safely fed to poultry and cattle, but for poultry, at least, the amount should be limited. Similar restrictions apply to certain feed ingredients such as cottonseed and rapeseed meals, feather meal and poultry by-product meal. For nonruminant animals castor pomace should be supplemented with lysine and methionine. The metabolizable energy of castor pomace for chicks is lower than that of soybean meal and digestible energy for steers is lower than that of cottonseed meal. Considering these restrictions, castor remains as an inexpensive source of protein. Its use in feed will be determined by its price relative to other protein sources.

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