Crambe Seed Processing: Improved Feed Meal by Ammoniation

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Abstract

An improved crambe meal has been developed by using an ammonia-heat treatment to give significantly better nutritive value and acceptability. The quantity of ammonia permanently bound as nitrogen in the processed meal was from 0.5 to 1.5% of the meal weight and varied with conditions of reaction. Destruction of the undesirable thioglucoside fraction of the meal was demonstrated by paper chromatograph changes and by the absence of the thioglucoside conversion product thiooxazolidone. Ultraviolet-absorbing compounds in the meal, at least one of which is associated with bitterness, were also modified. Feeding experiments with chicks and cattle show the improved palatability and nutritional quality. Incorporation of the ammonia reaction into desolventizer-toaster operations should be possible to provide an economical means of improving the feeding value of crambe meal.

Introduction

Industrial interest in Crambe abyssinica as a new oilseed crop is increasing as new potential markets for the oil develop; however, the economics of processing crambe for oil and meal depend on the meal serving as a successful protein supplement for livestock. Although crambe protein appears well-balanced in essential amino acids, conventionally prepared meal contains substances that are growth inhibitory and unpalatable to some animals.

Previously, we reported bench-scale filtration-extraction of crambe seed (9). Successful plant-scale processing of this oilseed by prepress-solvent extraction was also reported by Mustakas et al. (14). Both studies demonstrate that, provided reasonable precautions are taken, crambe seed can be processed by either prepress-solvent extraction or direct extraction to yield an oil low in free-fatty acids and with good refining and bleaching characteristics. The residue meal from both processes, however, presents problems for acceptance as an animal feed because it is growth inhibitory and goitrogenic to nonruminants (3,7,20) and unpalatable to ruminants (4). Since more than 1.25 tons of hull-free meal is produced per ton of oil, the overall economics of processing are influenced considerably by the value of this by-product.

Compounds in crambe meal responsible for the undesirable effects have not been clearly defined because pure fractions have not as yet been fed to test animals. Similarities between the major thioglucoside of crambe (6) and of rapeseed, however, leave little doubt that this meal constituent is responsible for crambe's goitrogenicity. This thioglucoside, epi-progoitrin, may also be responsible for crambe's growth inhibitory effects since Kirk et al. (9), VanEtten et al. (20) and Tookey et al. (17) have shown in rat-feeding experiments that growth is either much im-

1 Presented in part at the AOCs Meeting, Houston, April 1965.

TABLE I

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Dehulled seed</th>
<th>Prepress-solvent extracted meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>6.1</td>
<td>7.7</td>
</tr>
<tr>
<td>Crude fat</td>
<td>42.7</td>
<td>35.6</td>
</tr>
<tr>
<td>Protein (N X 6.25)</td>
<td>23.2</td>
<td>40.6</td>
</tr>
<tr>
<td>Thiooxazolidone content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free</td>
<td>1.09</td>
<td>0.99</td>
</tr>
<tr>
<td>Total</td>
<td>1.09</td>
<td>1.06</td>
</tr>
<tr>
<td>Thioglucoside</td>
<td>5.2</td>
<td>8</td>
</tr>
<tr>
<td>Sinapine</td>
<td>0.28</td>
<td>0.44</td>
</tr>
<tr>
<td>Reducing sugars as glucose</td>
<td>1.8</td>
<td>2.6</td>
</tr>
<tr>
<td>(2.5%)</td>
<td>(2.9%)</td>
<td></td>
</tr>
</tbody>
</table>

Includes both the free and the potential thiooxazolidone attainable after enzymatic hydrolysis.

A comparison of thioglucoside UV absorption peaks at 220 ma indicates that 90% of the original thioglucoside of the seed is retained in the process meal.

Per cent reducing sugars as glucose on moisture- and fat-free basis.
Fig. 1. Enzymatic hydrolysis of epi-progoitrin.

Thioglucoside $\rightarrow$ Isothiocyanate $\rightarrow$ Glucose

Thiooxazolidone

Reducing sugars were determined by the method of Munson and Walker (12) isolated from the meal as described by McGhee (10). Sinapine was determined by the method of Tzagoloff (18) with the modifications suggested by Austin and Wolf (2). Fat and nitrogen analyses were according to AOCS Official Methods (15).

Water extracts of crambe meals were chromatographed on paper by descending technique employing the top layer of an n-butanol:ethanol:water-solvent mixture in volume ratio 4:1:4 as developing solvent. The extract was prepared in the following manner: A 5-g meal sample was boiled 5 min in 60 ml of distilled water, held 10 min without additional heat and vacuum-filtered; the cake was re-extracted three times in 25 ml of hot water. The filtrates were combined and the total volume adjusted to 125 ml. A 10-μl sample of extract was spotted on the chromatogram. Thioglucoside and sugar spots were made visible by spraying or dipping first in a solution prepared by dissolving 0.5 ml of a saturated aqueous silver nitrate solution in 100 ml containing 2.5 ml of water and then in a solution prepared by the addition of a solution of four sodium hydroxide pellets (approximately 1 g) in 5 ml water to 100 ml of ethanol. Fluorescent spots were observed by exposure of the chromatogram to a "long-wave" UV lamp before spraying with silver nitrate.

Bound ammonia in the meals was determined by nitrogen analysis before and after ammoniation.

The rate at which the meals sorbed ammonia at atmospheric pressure was determined from a material balance based on the addition rate and the rate at which excess ammonia left the reactor. With ammonia entering from the bottom of the reactor at a rate greater than that at which it could be sorbed by the meal, the excess gas passed into the reactor headspace and vented through the condenser system. By periodically closing the vent and measuring the rate of pressure rise ($\Delta P/\Delta t$) in the headspace, it was possible to calculate the rate ($\Delta W/\Delta t$) at which excess ammonia was leaving the reactor during any stage of the ammoniation. The following ideal gas law relationship indicates the method of calculation:

$$\frac{\Delta W}{\Delta t} = \left(\frac{\Delta P}{\Delta t}\right) \times \frac{V}{RT} \times \text{mol wt NH}_3$$

where $\Delta W/\Delta t = \text{rate of ammonia leaving reactor in pounds per min}$, $\Delta P/\Delta t = \text{rate of pressure rise in inches of cone NH}_4\text{OH per min}$, $V = \text{reactor volume in in.}^3$, $T =$ the absolute temperature in °R, and $R =$ the gas constant equivalent to $5.72 \times 10^5$ (in. of NH$_4$OH) (in.)$^{-2}$ (pound mole)$.^(-1)$

The rate of ammonia sorption by the meal was then calculated as equivalent to the rate of ammonia minus $\Delta W/\Delta t$.

The quantity of ammonia removed during steaming and drying operations was determined by absorption in excess hydrochloric acid and titration with N sodium hydroxide.

The pressure-ammoniation equipment consisted of a jacketed spherical cooker of 12-in. internal diameter and rotated at 1 rpm. A rotary steam valve permitted maintenance of steam pressure in the jacket during rotation; however, it was necessary to stop the reactor for addition of ammonia. This apparatus is shown in Figure 2. A thermowell in the center and a pressure indicator for measurement of internal temperature and pressure complete the apparatus. Ammonia was added through the valve shown at the bottom of the cooker. Pressure-ammoniated meals were moistened and steamed in the 5-gal steam-jacketed cooker described by Mustakas et al. (13). The unit was equipped with an air-driven meshing-rod agitation system, steam sparge coil, spray nozzle and condenser.

Equipment for atmospheric ammoniation was a 1-cu ft ribbon blender (Fig. 3). Gaseous ammonia was introduced through a 1/8-in. hole in the discharge plug at the bottom. The lid was fitted with a spray nozzle for introduction of water and with a vapor outlet having a globe valve and water condenser. The con-

Fig. 2. Pressure reactor for ammoniation of crambe meal.