# ENGINEERING PROPERTIES AND SPOILAGE SUSCEPTIBILITY OF CANOLA MEAL

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## INTRODUCTION

Canola meal is obtained from canola seeds (rapeseed having low erucic acid levels in the oil and low glucosinolate levels in the meal; Brassica napus L., B. campestris L.), which have been processed by pressing and hexane extraction to remove the 40-45% oil content (w/w), which is largely used for human consumption. The meal is then used as a high-protein, animal-feed supplement. Canola meal is now largely handled in bags but bulk storage may become common as the quantities produced increase. In 1986, Canada produced nearly 4 million tonnes (Mt) of canola or about 20% of world production (Anonymous, 1987a). About 327,010 tonnes of canola meal with a value near 66 million dollars (Canadian) were exported from Canada to the United States, Japan, Indonesia, South Korea, and Norway in 1986 with the remainder used domestically (Anonymous, 1987b).

Little information is available in the literature on physical properties of canola meal or other similar textured material such as soybean meal. This information is needed to plan and design handling and storage systems for canola meal and canola meal pellets.

To predict safe storage conditions and drying behaviour of canola meal at various combinations of temperature and relative humidity, the relationship between equilibrium moisture and relative humidity of canola meal is required.

Also, little is known about physical limits for safe storage of canola meal either in temperate or hot-humid climates. Storage in tropical countries is especially difficult for most agricultural crops and their by-products because of temperature and moisture effects favouring insect infestations (Sinha and Watters, 1985) and rapid chemical deterioration (Pomeranz, 1982).

## OBJECTIVES

The objectives of this study were to (1) determine the physical properties of canola meal and pellets, such as bulk density, particle density, emptying and filling angles of repose and friction coefficients against plywood, concrete (steel-trowelled and wood-floated) and galvanized metal; (2) to determine desorption equilibrium relative humidities of canola meal samples at six moisture contents when brought into equilibrium with the moisture in air at five temperatures; (3) to determine safe storage times for canola meal at combinations of moisture and temperature in relation to physico-chemical changes; and (4) to assess the potential for infestation of the meal by storage pests, including insects, mites and microflora.

## EXPERIMENTAL METHODS

### Physical Properties of Canola Meal

Bulk density of samples was measured using the Canadian Grain Commission Standard (Anonymous, 1984) and by measuring the mass required to fill 4165 mL containers.

The containers were filled by dropping samples 1170 mm through a 44.5 mm diameter plastic pipe. The results from the second procedure were designated as pail density.

The particle volumes of the weighed samples were measured with an air comparison pycnometer (Model 930, Beckman Instruments, Inc. CA) and particle densities were calculated.

Emptying angles of repose were measured using a box 430 mm long, 200 mm wide and 430 mm high. Samples were placed in the box to a depth of about 350 mm and then allowed to flow out through a rectangular opening along the bottom of one narrow end wall. Surface profile was measured using a depth gauge with vertical and horizontal scales and emptying angles were calculated.

The filling angles of repose were measured in a box 1220 mm long, 100 mm wide, and 760 mm high with one side wall of plexiglass. The box was filled using a 53-mm-square opening wooden hopper located midway along the box length and 800 mm above the bottom of the receiving box. The angle of the filling slope was calculated from the measurements of the canola profile-depth at two points 335 mm apart (Kukelko et al., 1988).

Coefficients of friction against structural materials were determined by attaching the surfaces to a tilting table. On the surface, a frame constructed of square wooden bars, 18 mm thick, was placed lengthwise on the surface to enclose an area 305 mm long x 255 mm wide. The frame was filled with sample and carefully levelled off to frame height. The frame was then lifted slightly so that it was not resting on the surface. The table was tilted slowly by a manually driven screw. Angles at which samples started sliding were then measured with a plumb bob and a protractor.

All physical properties were measured for canola meal at moisture contents of 5.2, 7.5, 9.8, 12.7, 14.0 and 17.7% wet basis (wb) and for pellets at 10.5% moisture content (mc).

Sorption Isotherms for Canola Meal

The equilibrium moisture content - equilibrium relative humidity (EMC-ERH) relationship of canola meal was determined by bringing a small mass of air into equilibrium with a large sample mass of canola meal in a closed loop at a constant temperature. The relative humidity was monitored with time and recorded when equilibrium was attained (Jayas et al., 1988). The equilibrium relative humidity was measured for six moisture content levels (5.0, 7.5, 10.0, 12.5, 15.0 and 17.5% wb) at five temperatures (10, 20, 30, 40 and 50°C).

Determination of Safe Storage Conditions for Canola Meal

About 700 g of canola meal were placed in each of the forty plastic dishes which were placed in a sealed plastic container maintained at four constant relative humidities between 60 and 85% using aqueous KOH solutions of various concentrations. The containers were stored in environmental chambers at 10 ±1°C, 20 ±1°C, 30 ±1°C, 40 ±1°C and 50 ±1°C. Two containers, holding a total of 1.4 kg canola meal, were stored at each of the 20 storage conditions.

Samples of 100 g of canola meal were removed monthly from each storage environment, placed in plastic bags and held at -25°C until analyzed. Each sample was checked for moisture content and physical appearance which was mainly based on a colour change from yellow-green to brown (White and Jayas, 1989). At 0, 1, 3, 5, 7, 9 and 12 months of storage, free fatty acid levels, microfloral species present and their relative incidence (frequency of occurrence) were determined; at 1, 7 and 12 months, total fungal propagule counts were done for all samples.

Free fatty acid levels in canola meal samples were determined using the American Association of Cereal Chemists method 02-01 (Anonymous, 1962). Microfloral presence and relative incidence were determined using a method modified by Mills et al. (1978) from that of Wallace and Sinha (1962). Total fungal propagule counts were made using the methodology of Tuite (1969).

Distinct discoloration of the canola meal from yellow-green to brown was subjectively related to corresponding fat acidity values and used as a visual indication of deterioration.

Survival and Development of Insects and Mites on Canola Meal

Fifteen species of stored-product insects and two species of stored-product mites taken from laboratory cultures were placed on canola meal of 11.0% mc and held at 30 ±1°C and 65 ±5% rh. Twenty-five adults of each insect species or 50 adults of each mite species were placed in 397-mL bottles with 100 g of canola meal. Living or dead adults and larvae were counted after 1 and 3 months in six bottles per species at each time (17 species x 6 bottles x 2 times = 204 bottles).

## RESULTS AND DISCUSSION

Density

The mean (n=4) pail bulk densities increased gradually for canola meal from 574 kg/m$^3$ at 5.2% mc to 581 kg/m$^3$ at 12.7% mc and then dropped to 513 kg/m$^3$ at 17.7% mc. The Canadian Grain Commission standard bulk densities also followed a similar trend rising from 564 kg/m$^3$ at 5.2% mc to 572 kg/m$^3$ at 9.9% mc and falling to 498 kg/m$^3$ at 17.7% mc. The maximum difference between the Grain Commission standard and the pail bulk density was 35 kg/m$^3$ at 12.7% mc (Kukelko et al., 1988).

Particle density for the canola meal was relatively constant over the moisture range with a mean value of 1326 kg/m$^3$. The particle density of the canola meal pellets was 1392 kg/m$^3$ which was 4.74% higher than for canola meal. For a given mass, canola meal pellets are more compacted and thus an increase in particle density is reasonable. Deviations among replicates for all density measurements at all moisture contents were less than 1.9% from means. Deviations among replicates for pellets were slightly lower than the deviations for canola meal samples.

Emptying and Filling Angles of Repose

Canolal meal profile during emptying gave two distinct slopes which were identified as upper and lower angles. Both the upper and the lower emptying angles increased with the increase in moisture content. The upper emptying angle for canola meal increased sharply from 45.4 degrees to 69.9 degrees when moisture was increased from 12.5% to 14.8%.

The filling angle remained nearly constant over the moisture range of 5% to 17.5%. It is postulated that the cohesiveness of canola meal particles during filling is not moisture dependent between the range of 5% to 17.5%.

Friction Coefficients

It was observed that canola meal particles often tend to become imbedded in the surface of the structural material which they are placed against and therefore, part of the friction coefficient measured is believed to be an internal friction angle created when particles of the canola meal slide on the canola meal imbedded in the surface. The imbedding in the surface was most prevalent on the rough concrete surface and was nearly non-existent on the galvanized steel surface. The degree of imbedding in the surface was an unpredictable occurrence and no attempts were made to quantify the percentage of imbedding. If 100% imbedding did occur, the angle of friction would be equal to the internal friction angle.

The friction coefficients for plywood parallel to the wood grain, gradually decreased from 0.44 at 5.2% mc down to 0.41 at 7.5% mc and increased back to 0.57 at 17.7% mc. The values for steel-trowelled concrete also first decreased with increasing moisture content and then rose steadily to 0.67 at 17.7% mc. The results for wood-floated concrete showed a slow rise from 0.56 at 5.2% mc to 0.63 at 14.0% mc before climbing to 0.68 at 17.7% mc. The coefficient of friction against galvanized steel rose gradually when moisture was increased from 5.2% to 14.0% and then rose sharply. The coefficient of friction jumped from 0.38 to 0.58 with a moisture content increase from 14.0% to 17.7% (Kukelko et al., 1988).

EMC-ERH Data

The mean values of the equilibrium moisture content (dry basis) and the equilibrium relative humidity at various temperatures are plotted in Fig. 1. Based on three replicates, the coefficients of variation [(standard deviation/mean) x 100] were calculated for measured moisture contents. The variation in moisture measurements was less than 0.3% for most of the test conditions. On the average, the variation in temperature and relative humidity measurements was 0.8 and 1.7%, respectively.

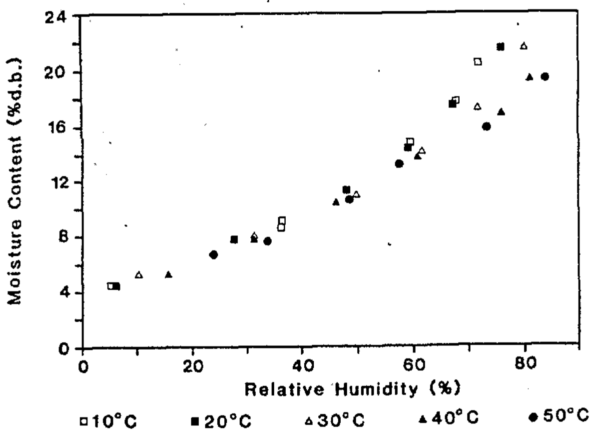


Fig. 1 Equilibrium moisture content-equilibrium relative humidity data for canola meal at various temperatures.

The effect of temperature on the moisture desorption isotherms of canola meal is negligible at moisture content below 15% wb (Fig. 1). At higher moisture contents, an increase in temperature results in higher relative humidity at a constant moisture content. Labuza et al. (1976) stated that if isotherms are plotted in the direction of increasing temperature the trend is increasing relative humidity with constant moisture. In other words, the amount of water the material can hold is decreased with increasing temperature and this water is released into the surrounding environment.

Safe Storage Conditions

The oil content of the canola meal was 5.3% (w/w). The initial fat acidity value (FAV) was 43.7 mg KOH/100 g canola meal. The values remained relatively low during 12 months at 10 and 20°C and rates of increase were directly related to temperature and moisture content. Deterioration was rapid at 40 and 50°C and discoloration did not directly correspond to fungal incidence or propagule counts, although there was a strong relationship with bacterial incidence White and Jayas, 1989. Increases in FAV are known to reflect product deterioration (Pomeranz, 1982). A notable decrease in FAV at 12 months at 40°C, 11.5% mc was related to a decreased amount of oil which may have been degraded by microbial activity. Summary of these data (Fig. 2) indicated that canola meal can be safely stored for more than 12 months at temperatures below 30°C and 7% mc while it can be stored for only 3 months at 40°C and 6% mc. Deterioration is very rapid at 50°C and at this temperature meal can be stored only 1 month at 6-8% mc. Storage conditions near this temperature and at high moisture contents might be encountered in bagged canola meal stored in warehouses in tropical countries.

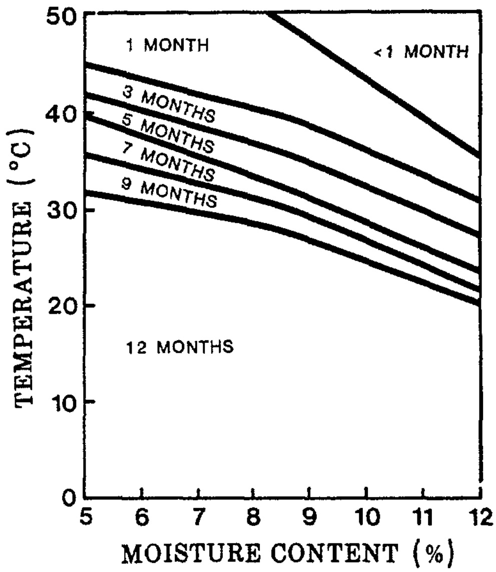


Fig. 2 Estimated safe storage times for canola meal based on initial color change from yellow-green to brown and on fact acidity values below 88 mg KOH/100 g canola meal.

Survival and Development of Insects on Canola Meal

Fifteen species of stored-product insects and two species of stored-product mites were exposed to canola meal for up to 3 months to determine which arthropods could be potential pests. Only Tribolium spp. could survive and multiply on the canola meal in 3 months. Tribolium spp., especially T. castaneum (Herbst), are the most adaptive stored-product insects in the world to various environments and foods (Sinha and Watters, 1985). T. madens (Charp.) multiplied most successfully on canola meal producing about 25% as many offspring as on cereal diets. Stegobium paniceum (L.) produced larvae which survived but they had not matured in 3 months; their usual developmental time on suitable food is 40 days (Sinha and Watters, 1985). Only one Tenebrio molitor L. larva survived 3 months. Canola meal, even at near-optimal moisture conditions and temperatures for insect development, is not a suitable food for most common stored-product insects or mites. Infestations seem unlikely, possibly because low levels of carbohydrate and residual levels of about 5% oil (w/w) in the canola meal may inhibit development. Soybean meal which is similar in amino acid, mineral and vitamin composition (Daun, 1982) can be infested by insects (Cox and Simms, 1978).

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