Predicting the Moisture Isotherm for Corn-Soy Milk from Individual Component Moisture Isotherms and Their Possible Effects on Storage Stability

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ABSTRACT

Moisture isotherms for the blended food product corn-soy milk (CSM) and for the individual hygroscopic constituents of CSM are reported at 25° C. Isotherms were used to predict the moisture content of each constituent after blending by applying a procedure previously developed for dehydrated food. Nonfat dry milk in CSM formula 2 increases in moisture content from 4.0 to 8.2% because of the moisture transfer from the soy flour, which decreased from 10.0 to 8.9% moisture.

Laboratory studies (Bookwalter et al 1968, 1971a, 1971b, 1980) and field experience indicate that corn-soy milk (CSM) has adequate storage stability at temperatures less than 50° C. However, CSM exposed to abnormally high temperatures can be subject to nonenzymatic browning (Bookwalter and Kwolek 1981). CSM moisture content may also be a causative factor. In the manufacture of CSM, processed cornmeal at 11% maximum moisture, defatted soy flour at 10%, and nonfat dry milk at 4% are blended with vitamins, minerals, and soy oil, with the final specified maximum moisture at 10% (USDA 1975). Because the differences in the moisture contents of the ingredients are so large, we were interested in examining the moisture isotherms of the individual components to determine the source of potential browning and whether such deteriorations could be predicted based on the isotherms.

MATERIALS AND METHODS

To determine the individual isotherms, fresh samples of partially gelatinized cornmeal, defatted and toasted soy flour, and nonfat dry milk (NFDM) were obtained from commercial sources. The samples were dried 16 hr at 60° C in a vacuum oven, then exposed to an ethylene oxide atmosphere for 1 hr to eliminate indigenous microflora. Moisture contents (wet basis) after drying were 1.0% for the cornmeal, 2.6% for the soy flour, and 3.0% for the NFDM.

The isotherms were determined by the static desiccator method (Wink 1946). Desiccators containing various saturated salt solutions were used to provide the range of relative humidities needed. Nine salts at the following relative humidities were selected: zinc chloride, 7.4%; potassium acetate, 23%; magnesium chloride, 33%; potassium carbonate, 44%; calcium nitrate, 51%; sodium nitrite, 63%; sodium chloride, 74%; potassium chloride, 83.5%; and potassium nitrate, 91.5%. The equilibrium relative humidity (erh) of each salt solution was measured before the samples were placed into the desiccators, using a Hygrodynamics model IS-3050 hygrometer. The salt solutions were maintained at 25 ± 1° C during the tests.

The weights of the samples used in the test were approximately 4 g for the cornmeal, 1 g for the soy flour, and 2 g for the NFDM. These sample sizes gave a uniform single layer in the petri dish and were chosen after preliminary tests indicated that multilayer samples (especially of the soy flour and the NFDM) tended to harden on the surface, causing increased resistance to moisture transfer. This necessitated significantly longer periods to attain equilibrium. Samples of each constituent and the blended CSM product (cornmeal, 63.8%; soy flour, 24.2%; NFDM, 5.0%) were placed in open-top petri dishes in the desiccators. After the fifth day, the samples were removed daily and weighed. One desiccator was continuously monitored with the hygrometer during the test; less than 20 min were required for the atmosphere in the desiccator to return to corresponding relative humidity after weighing. Equilibrium of the samples was determined by the constant weight of sample between weighings. After equilibrium was reached (generally after six or seven days), moisture contents of the samples were determined by the standard 72-hr oven method at 105° C. Duplicate runs were made at each relative humidity.

RESULTS AND DISCUSSION

The results of the moisture isotherm determination for the CSM constituents are shown in Fig. 1. The data point for NFDM at 44% rh appears to deviate considerably from the isotherm line. However, Berlin et al (1968) showed that in this region the crystallization of lactose from an amorphous glass to the α-monohydrate form occurs during the first adsorption cycle. The adsorption curve can be drawn to include this point, but in this analysis, the data point should be ignored and the adsorption curve smoothed.

Figure 2 shows the moisture isotherm for the blended CSM product. The data points are experimentally determined, whereas the dashed line is the isotherm calculated from the composite of the individual isotherms of the constituents.

Following the procedure outlined by Salwin (1963) and Salwin and Slawson (1959), the above isotherms can be used to predict the erh of the blended CSM mixture and the equilibrium moisture content of constituents in the mixture. The erh for a mixture of n ingredients can be predicted by the equation:

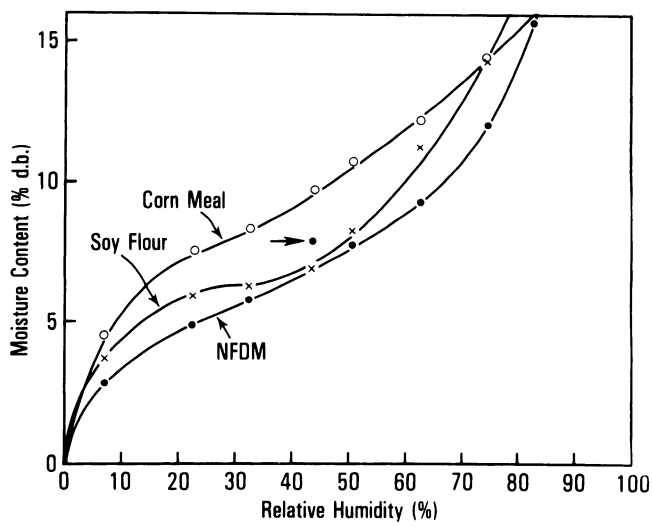

Fig. 1. Moisture content and relative humidity sorption isotherm for the three component ingredients of CSM at 76° F.

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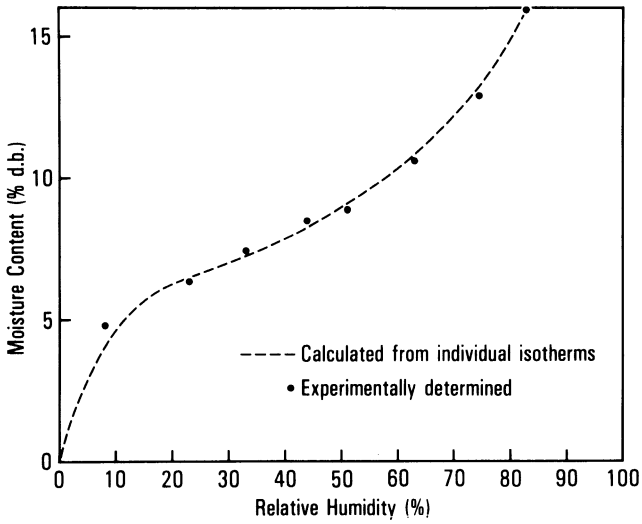

Fig. 2. The moisture content and relative humidity sorption isotherm for corn-soy meal at 76° F.

$$R_E = \frac{\sum^{n} R_n S_n W_n}{\sum^{n} S_n W_n,}$$

where R_E is equilibrium relative humidity of the mixture, and R_n is equilibrium relative humidity of the n^{th} constituent before mixing. W_n is the dry weight of the n^{th} constituent, and S_n is the slope of the sorption isotherm between the initial relative humidity of the n^{th} constituent and the equilibrium relative humidity of the mixture.

This procedure was used to predict the isotherm shown in Fig. 2 for the blended CSM product. Good agreement was achieved with the actual experimental data. When this procedure is applied to the CSM product formula 2, which is composed of 63.8% cornmeal, 24.2% soy flour, 5.0% NFDM, 2% minerals, and 5.0% soy oil, the erh of the mixture is 55% for the maximum allowable initial moisture contents of 11.0% for cornmeal, 10.0% for soy flour, and 4.0% for NFDM. One must first assume the final erh to calculate isotherm slopes. If the calculated erh differs from the assumed value, then an iterative procedure can be undertaken until agreement is achieved.

At 55% erh for the mixture, the moisture contents are 8.2% for the NFDM, 8.9% for the soy flour, and 11.2% for the cornmeal. The soy flour and cornmeal are stable at these moisture contents, but the NFDM is unstable, according to the work of Kliman and Pallansch (1968) and Nguyen et al (1968), in which nonenzymatic browning was shown to occur in NFDM when the moisture content is above 4%. Samples of NFDM held at 50° C or above at high moisture contents will undergo chemical changes after 24 hr. The chemical changes involve formation of precursors of the discoloration that is associated with the browning reaction.

The good storability of CSM below 50° C is most likely the result of maintaining the final moisture content of the blended product at less than 10% and of storing in moisture-resistant bags. Good storability may also result from the dilution of NFDM during the blending, which might preclude or mask deterioration of NFDM, which occurs at higher temperatures and elevated moisture levels.

This is supported by data from Bookwalter et al (1980), in which formulations with 5% NFDM required higher temperature or longer storage time to exhibit browning (measured both visually and by Hunter color difference meter) as compared with a 15% NFDM formulation. A delay in the visual indications of browning, as compared with bulk NFDM, would result.

As the temperature is increased, the constituent isotherms shift downward, and one should question whether the isotherms determined at 25° C would be applicable to processes occurring at 50° C. If the CSM bag was an open system and able to exchange moisture with the surroundings, the results would not be transferable. However, because the CSM is sealed in water-tight bags, an increase in temperature would increase the vapor pressure within the bag, thus increasing the erh of the CSM, but only slightly affecting the moisture content of the CSM. The only moisture loss of the sample would be the small quantity necessary to increase the water vapor pressure in the void space and head space of the bag. Temperature increases do not significantly change the partitioning of the moisture of the various constituents. Consequently, the decrease in storability at 50° C may be caused by the shift to a higher equilibrium relative humidity and by temperature. Both factors cause the deterioration to accelerate.

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