FOOD PRODUCTS FROM CORN GERM: EVALUATION AS A FOOD SUPPLEMENT AFTER ROLL-COOKING

SUMMARY—The composition of corn germ indicates that it may have value as a nutritious food supplement. Heated rolls were used to cook a full-fat flake to products with varying pasting qualities depending upon the temperature of the rolls and the temper moisture of the germ before rolling. A germ flake with improved taste was produced if the temperature of the rolls was held above 126°C. The flavor of the flakes was unchanged after 120 days' storage at 37°C and 7% moisture levels. Oil extracted from the 120-day stored flakes had low peroxide values (low, 1.6 meq/kg oil; high, 17.8 meq/kg oil). The peroxide values were especially low in oil from uncooked germ and germ cooked at a low temperature (99°C). When flakes were stored at 13.5% moisture, mold developed on them within 30 days.

INTRODUCTION

THE POTENTIAL of corn germ as a food has been recognized since the turn of the century. As indicated by the number of papers published during the 1940's on the nutritive value of corn germ, World War II precipitated interest in supplementing food supplies with new materials. Discussing the use of corn germ as a food, Mitchell and Beadles (1944) appropriately wrote, "In times of food stringency, such as are with us now and will stay with us until the havoc of war has subsided, the most economical use of available food supplies is imperative, and the introduction of new food materials should be welcome." The world is again approaching a period of food stress, which probably will not be alleviated with the passage of time. New sources of nutritionally balanced protein must be recognized and utilized.

A review of compositional data revealed the nutritional potential of corn germ. Corn germ hand-dissected from a number of genotypes was composed of the following materials, for which mean percentage values and a range of values (on a moisture-free basis) were reported (Earle et al., 1946): protein, 18.8 (17.3–20.2); fat, 34.5 (31.1–38.9); ash, 10.1 (9.16–11.3); sugar, 10.8 (9.87–12.5); and starch, 8.2 (5.1–10.0). Corn germ obtained from commerce (dry-milled, or wet-milled with or without extraction of the oil by solvents or expeller) is inherently changed in composition. The germ fraction from dry milling is a mixture, including bits of pericarp and endosperm that decrease the protein and oil contents. After the oil is extracted, the protein content is increased to about 24% (Joint U.S.-Canadian Tables of Feed Composition, 1964). The germ fraction from dry-milled corn germ, especially for its protein and oil contents. After the oil is extracted, the protein content is increased to about 24% (Joint U.S.-Canadian Tables of Feed Composition, 1964).

The favorable compositional data are reinforced by nutritional studies which were reviewed by Stare and Hegsted (1944). In rat-feeding studies the protein efficiency ratio (PER) (g of wt gain/g protein fed) of germ averaged 2.1 with values ranging between 1.8 and 2.4 when the germ was fed in a diet adjusted to a 10% protein level (Block and Bolling, 1943; Beeson et al., 1947; and Jones and Widness, 1946). The PER values for corn germ are comparable to those determined for soybeans (Jones and Widness, 1946) or whole milk powder (Block and Bolling, 1943). Biological values (BV) (wt of nitrogen retained x 100/wt of nitrogen absorbed) and coefficients of true digestibility were favorable for corn germ (Mitchell and Beadles, 1944; Murlin et al., 1946; Schulz and Thomas, 1949a, b). The BV averaged 70.8, ranging from 64–83, and the coefficient of true digestibility averaged 80 with a range of 70–85. A 10% protein diet of solvent-extracted dry-milled germ produced a BV equivalent to beef, but was only about 85% as digestible (Mitchell and Beadles, 1944). Schulz and Thomas (1949b) noted that expeller-processed germ had a lower BV compared to solvent-extracted germ possibly owing to high temperatures of processing.

Precooked oilseeds and cereals are being increasingly utilized in blended formulas for low-cost nutritious foods. Techniques of cooking by heated rolls have been reported for both oilseeds and cereals. Anderson et al. (1969) outlined the conditions of temperature and temper moisture levels that required to achieve optimum cooking of corn grits. They measured the amount of cooking by the degree of starch gelatinization. Precooked peanut slurries have been dried on heated rolls to give a flake with improved taste (Mitchell and Malphrus, 1968). Extrusion-cooking, similar in principle to roll-cooking, was investigated with soybeans (Mustakas et al., 1964), cottonseed (Clark, 1969) and soy-corn products (Muelenaere and Buzzard, 1969).

A food supplement developed for preschool children, consisting of a formulation of heat-processed corn meal, soybean meal, nonfat dry milk, vitamins and minerals, has been shipped to developing countries under the Food for Peace Program since September 1966. This cornsoya-milk formulation (commonly called CSM) may include corn germ in the blend to satisfy the 6% fat requirement (USDA, 1969). Because more widespread use of corn germ in foods appears imminent, we studied the composition of a sample of dry-milled corn germ, especially for its amino acid content. The germ was roll-cooked at various temperatures and temper moisture levels. The organoleptic qualities, pasting properties and storage stability of the cooked germ were evaluated.

MATERIALS & METHODS

Source of corn germ

Corn germ, furnished by General Foods, Kankakee, Ill., was taken directly from the dry-mill germ stream. The history of the corn was unknown, but millers generally use corn of U.S. grade No. 2 or better. The germ (analyzed at 17% moisture) was dried for 34 hr to 10.8% moisture, until used for the roll-cooking experiments. The germ used in organoleptic evaluations and experiments of a confirmatory nature was stored 7–8 months prior to cooking. We did not detect any significant change in...
the germ for over a year of storage under the above conditions, except for a decline in enzyme activities.

Roll-cooking of germ

The various samples of corn germ were cooked on both steam and gas-fired double rolls, maintained at 3 rev/min with a clearance set cold at 0.001 in. The germ samples, exposed to heat for 0.20 min, were first tempered to 20, 25 or 30% moisture content 1 hr before rolling.

Organoleptic evaluation

For organoleptic evaluation samples of roll-cooked and unprocessed germ were submitted to a taste panel composed of 15 laboratory employees, who were given a minimum of training prior to tasting. Not all members of the panel were required to taste each sample. The design of the sampling technique was an "incomplete latin square" (Cochran and Cox, 1964), which results in eight individual judgments rendered per sample even though 15 judges participate in the panel. Odor and flavor scores were based on a 10-point score sheet as outlined by Bookwater et al. (1968). In addition, the taste panel was asked to write down a statement if any unusual odor or odor property was detected. Mean taste scores for all samples in each trial were compared by application of Duncan's method (1955) of least significant difference factors.

Storage stability

Studies of storage stability of germ were carried out in glass containers stored in an oven set at 37°C ± 1°C. The moisture contents of the germ flakes were adjusted to the appropriate values by adding or withdrawing a calculated amount of water with thorough mixing or by vacuum desiccation at room temperature. Samples were withdrawn from storage after 30 and 120 days for organoleptic evaluation and analyses of oil quality.

Analytical methods

Moisture, ash, fiber, protein (AOAC, 1965) and crude fat (AOAC, 1960) were determined by standard procedures. After sugar was extracted from the germ exhaustively with 80% hot ethanol, the extract was dialyzed to equilibrium, and the sugars in the dialysate analyzed with the phenol-sulfuric acid method (Dubois et al., 1956). Amino acid compositions were determined as described by Benson and Patterson (1965). Peroxide values of the germ oil were analyzed by the standard AOS (1961) method.

Oil was extracted from germ with chloroform-methanol 2:1 (v/v), and the filtered extract was evaporated to dryness on a rotary evaporator at 40°C. A 40-ml mixture of hexane-water 1:1 (v/v) was added to the residue and mixed thoroughly, after which the hexane layer was recovered and evaporated to dryness at 40°C. Oil was freed of traces of solvent by a rapid flow of N2 to constant weight. Residual matter suspended in the oil was removed by centrifugation.

Water absorption index (WAI) for measuring pasting properties (Anderson et al., 1969) was used with some modifications. By the modified method the germ was defatted with chloroform-methanol 2:1 (v/v) followed by extraction with 95% ethanol. Defatted germ was ground without undue heating to ~40 mesh (U.S. Standard Sieve), and the ground germ was soaked by the specified procedure. A 0.1% solution of Triton X-100 was used in the soaking procedure instead of distilled water.

RESULTS & DISCUSSION

Gelatinization by heated rolls

The effects of roll temperatures and of temper moisture on the gelatinization of starch in germ were studied. An estimation of starch gelatinization was based solely on an empirical method, the WAI. The WAI has been used to study the gelatinization of corn grits by Anderson et al. (1946), who noted that WAI increased with increasing cooking temperatures until about 350°F (177°C), a temperature which limited the WAI value. Table 1 illustrates the effects of both temper moisture and temperature on the WAI of corn germ. In Figure 1 WAI values are plotted as predicted isometric projections, which were calculated by fitting a second degree equation by the method of least squares to the mean WAI (the temperature conditions of 177°C and 204°C were omitted in the calculation). The fit of the equation

WAI = 7.11 - 0.0630 T - 0.0087 M + 0.00026 T² + 0.00014 M² + 0.00036 M T

where M is % moisture, and T is roller temperature in °C was highly significant. An increase in temper moisture from 20 to 30% while maintaining constant WAI would require about a 19°C decrease in roll temperature (Fig. 1). WAI values of germ processed at 177°C and 204°C (Table 1) became highly variable and rather low indicating that the limit to increasing WAI may have been approached. At both temperatures a toasting color was apparent.

Gelatinization as measured by WAI is significantly affected by the amount of endosperm mixed with the germ fraction. While endosperm averages 86% starch, the average for germ is only 8.2% (Earle et al., 1946). Thus a purer germ sample, as might be obtained by screening the dry-milled germ fraction, would be expected to yield lower WAI values with smaller effects associated with heating.

Germ composition

Potentially, flaked corn germ could be used as a protein supplement for cereal-based foods. The quantity and quality of the protein in cereal blends demand critical attention during formulation to achieve proper amino acid balance for human needs. Table 2 shows that the dry-milled germ fraction used in this study had a much higher protein content than would be expected in corn products derived strictly from the endosperm (grits, meal or flour). The quality of germ protein is also superior to endosperm protein, which is especially deficient in lysine. Table 3 reports a complete amino acid analysis of the dry-milled germ before and after cooking at 177°C with heated rolls. The content of lysine in the germ samples was considerably greater

| Table 1—Mean water absorption index for various conditions of roll temperature and temper moisture |
| Roll temp (°C) | Percent moisture |
| 99 | 3.14 ± 0.11b |
| 124 | 3.40 |
| 141 | 3.99 |
| 149 | 4.66 |
| 177 | 5.03 |
| 204 | 5.33 |

*Least significant difference = 2 x 0.185 √2/3 = 0.30.
*Standard error of mean of three values obtained from replicate roll-cooking runs.

| Table 2—Proximate analyses of dry-milled corn germ compared with hand-dissected corn endosperm |
| Analysis | % compositionb | Endospermb |
| Protein | 15.4 | 9.4 |
| Fat | 19.8 | 0.8 |
| Fiber | 5.7 | 0.8 |
| Ash | 5.6 | 0.3 |
| Sugar | 5.5 | 0.6 |

*Calculated on a dry weight basis.
*Data from Earle et al. (1946).

| Table 3—Amino acid content of untreated and roll-cooked a corn germ |
| Amino acid | Untreated | Roll-cooked |
| Weight g/100g | Weight g/100g |
| Lysine | 0.77 | 4.9 |
| Histidine | 0.42 | 2.7 |
| Ammonia | 0.29 | 1.8 |
| Arginine | 1.1 | 6.9 |
| Asparitic | 1.1 | 7.1 |
| Threonine | 0.56 | 3.6 |
| Serine | 0.69 | 4.4 |
| Glutamic | 2.6 | 17.2 |
| Proline | 0.89 | 5.7 |
| Glycine | 0.70 | 4.5 |
| Alanine | 1.1 | 6.8 |
| 1/2 Cystine | 0.29 | 1.8 |
| Valine | 1.1 | 6.8 |
| Methionine | 0.29 | 1.8 |
| Isoleucine | 0.54 | 3.4 |
| Leucine | 1.3 | 8.4 |
| Tyrosine | 0.55 | 3.5 |
| Phenylalanine | 0.60 | 3.8 |
| Total N | 2.52 | 2.44 |

*Calculated on a dry weight basis.
than in corn endosperm, which is about 0.15 wt percent in lysine (Inglett et al., 1969).

As indicated by Table 2, the dry-milled germ fraction was 19.8% oil. Formulating full-fat germ flakes in foods adds oil rich in the essential fatty acid, linoleic acid, and in tocopherols and saves the cost of adding more expensive refined oils. Crude oils are known to contain more tocopherol than refined oils (Herting and Drury, 1963).

Minerals are concentrated in the germ rather than the endosperm, as indicated by the high ash content of germ (Table 2). Because phosphate and many cations are bound as phytate (Inglett, 1970b), these minerals are partly unavailable.

Roughage material in dry-milled germ may be a major disadvantage to its acceptance as a food. A high fiber content is reported in Table 2. Likely, bits of pericarp (hull) and tip cap mixed in the germ fraction contributed to fiber content. Lowering this fiber has been accomplished in our laboratory by removing the pericarp and other fibrous contaminants by screening and aspiration.

Another component of germ that must be classified as roughage material, is hemicellulose, fully characterized by Feather and Whistler (1962). According to them, hemicellulose amounts to 14.7% of the germ. We have been unsuccessful in finding a practical method of removing hemicellulose.

Sensory evaluation

Cooking germ with heated rolls yielded a light yellow flake whose appearance was generally good, although black specks in the flakes were detrimental to appearance. The specks were due to the hilar layer situated at the outer portion of the germ adjacent to the tip cap in the intact kernel. In recent years, however, the consumer has learned to accept black specks in some corn snack foods.

Flavor and odor properties were evaluated by a taste panel. Differences in odor scores among the samples of germ flakes were not of the magnitude observed for flavor scores. Consequently, no significance could be attached to the odor data in most tests. When significant differences were observed, the odor values usually paralleled flavor scores. In general, undercooked germ has a slightly "raw" odor, whereas sufficiently cooked flakes often have an odor of roasted corn.

Roll heating significantly changes flavor as reflected by differences in the scores among samples. Rolled flakes were usually crisp with a good "mouthfeel." The factor of mouthfeel undoubtedly affects flavor scores, which would lead to erroneous conclusions regarding the true flavor. When the flakes were tasted "as is" after roll heating (3-16% moisture), the scores often were inversely correlated with moisture content and usually correlated directly with WAI (Fig. 2). A low moisture and high degree of gelatinization would probably be related to crispness. In order to eliminate the crispness effect and to concentrate attention on other factors of taste, the moisture of the flakes was adjusted to a uniformly high value of 13.5% for further tests. After moisture was adjusted, the flavor scores no longer correlated strictly with WAI over ca. 4 as indicated in Figure 2. Low flavor values with flakes of low WAI are probably due to factors other than mouthfeel, such as the raw taste encountered with undercooked germ.

A characteristic taste distinguished raw and undercooked germ from germ flaked with rolls kept at sufficiently high temperatures. The flavor of undercooked samples was most often described by the taste panel as "raw" or "stale" with a bitter aftertaste. The flavor was similar to that of raw soybeans, except the bitterness and raw flavor of corn germ was not nearly so intense. The raw or stale taste seemed to be eliminated at higher roll temperatures, while the bitter aftertaste diminished in intensity. Slightly bitter aftertaste lingered in most samples. Figure 3 shows the effect of heat on flavor scores. Uncooked germ and germ treated at 99°C were consistently rated lowest in flavor, whereas treatment at 124°C with temper moistures of 20 and 25% were borderline in flavor between undercooked germ and germ treated at higher temperatures. However, acceptable flavor was obtained at 124°C and 30% moisture. Roll temperatures between 141°C and 177°C gave acceptable scores and uniform taste properties. Roll temperatures over 177°C yielded toasted products, which were different in flavor properties. Toasted flakes compared in flavor scores to those cooked between 141°C and 177°C.

Storage stability

Germ flakes stored at 37°C with 7% moisture retained the same flavor for 120 days regardless of the roll-cooking conditions used. Taste tests conducted after 30 and 120 days' storage were well within the least significant differences in flavor scores when compared to unstored samples. The least significant differences of the taste scores were 1.60 for 30 days, 1.46 for 120 days and 1.18 for zero time.
REFERENCES
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