Effect of Corn Moisture on the Properties of Pet Food Extrudates[1]

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ABSTRACT

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Corn moisture (9.5–13.5%) was significantly correlated to extrudate properties, even though water was added at the extruder to compensate for the differences in moisture. Water addition was more effective at the preconditioner than at the extruder, and longer retention preconditioner improved expansion. Water added to the pet food formula apparently was absorbed by the other formula ingredients and not the corn. Controlling the specific mechanical energy did not compensate for differences in corn moisture.

Cereal grains are the basic ingredients for most extruded snacks and pet foods (Mercier et al 1989). A number of studies have shown how various process variables affect the quality of extrudates (Meuser et al 1987, van Lengerich 1990). In a recent study, Mathew et al (1999a) showed that the type of mill used to grind the corn and the particle size of the meal also had large effects on extrudate quality. That study also showed that commercial corn samples obtained from different parts of the country affected extrudate quality. In a subsequent study (Mathew et al 1999b), it was shown that both environment under which the corn was grown and the corn genetics were important in determining the corn extrusion properties. They suggested that the level of starch in the samples may control the expansion during extrusion. In their study, the corn moisture content only varied over a narrow range (11 ± 3%). The objective of this study was to determine whether differences in corn moisture content affects the extrusion properties of pet foods. In addition, the addition of water at various points in the system was studied.

METHODS AND MATERIALS

A series of corn hybrids grown at a number of locations in Iowa (Johnston, Creston, Nevada, and Algona) and single locations in Nebraska (Doniphan) and Illinois (Central IL, CIL) were furnished by Pioneer Hi-bred International. The corn samples were dried in the field to moisture levels in the range of 9.5–13.5%. The hybrids, their locations of growth, and their analyses are given in Tables I and II. Two samples of commercial corn with moisture contents of 13.4 and 9.6% obtained from the KSU feed mill were used for certain experiments. Statistical analyses were preformed using the Statistical Analysis System (SAS Institute, Cary, NC).

Extrusion of Pet Food

A generic pet food formula as provided by Friskies Research and Development Center, St. Joseph, MO, consisting of ground corn and a proprietary base mix (whole corn, poultry by-product meal, corn gluten meal, soybean meal, and salt) was used in the study to produce extruded pet food. The corn was first hammer-milled using a Jacobson tear-drop hammer mill through a 4/64" (1.500 mm) screen and then reground with the same mill but through a 3/64" (1.125 mm) screen. The ground corn was mixed 1:1 with the base mix and blended using a Wenger ribbon batch mixer (capacity: 250 lb, 113.5 kg) for 15 min/batch. The mixed corn plus base mix then was stored in cardboard drums until used. All extrusion runs were conducted using a Wenger TX-52 twin screw extruder (Wenger Manufacturing, Inc., Sabetha, KS) at Kansas State University. Extrusion conditions were described by Mathew et al (1999a).

Corn Analyses

Proximate analysis, 100 kernel weight, test weight, absolute density, kernel size, 10 kernel width, starch content, and particle size were determined as described by Mathew et al (1999b).

Effects of Retention Time in Preconditioner on Extrudate Properties

A test to determine the effect of preconditioner retention time on bulk density of pet food extrudate was conducted with a commercial corn sample. All treatments used the pet food formulation described earlier. The corn had a moisture content of 13.4%. The corn was dried to 11.2% moisture in the Wenger two-pass dryer set at 55°C. The dryer conditions were 20 min of drying on the top conveyer belt, 40 min of drying on the bottom conveyor belt, and 5 min of cooling time. The dried corn sample was divided into two subsamples and both were extruded with the same processing conditions except for preconditioner retention times.

Preconditioner retention times of 106 and 184 sec were achieved using different configurations for the differential diameter chamber (DDC) of the preconditioner (Mathew 1996). For determination of retention time, the preconditioner was operated with the desired feed rate, water rate, and steam rate. After the system was stabilized, all controls were shut down simultaneously, and the meal in the preconditioner was collected and weighed. The retention time was calculated as the ratio of the weight of meal obtained from the preconditioner to the total mass flow rate (meal feed rate + water rate + steam rate) through the preconditioner.

To study the moisture absorption characteristics of a corn fraction during preconditioning of pet food meal, a second sample of commercial corn (9.6% moisture) was hammer-milled through a 1/16" (1.59-mm) screen and sieved using a 24-wire mesh. The overs were collected, and the fines were discarded. The overs were then mixed with the base mix (1:1) according to the pet food formulation and run through the preconditioner with water and steam supplied at the required rate for pet food processing. Preconditioned meal was collected and sieved over a 24-wire mesh to separate the corn and base mix, and the moisture contents of corn and base mix were determined.

Effect of Specific Mechanical Energy on Bulk Density of Pet Food Extrudate

Four corn samples that varied in moisture content (hybrid 3162 grown at Creston and Johnston, IA, and 3394 grown at Creston and Nevada, IA) were selected. The moisture contents varied from 9.7 to 11.2%. The four samples were extruded as indicated above, except the screw speed range was 400 to 375 or 350 rpm. Thus, the extruder motor load was changed, causing significant changes in the specific mechanical energy (SME) input. This allowed us to determine the effect of SME on bulk density of wet extrudate.

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RESULTS AND DISCUSSION

Effect of Corn Moisture Content

As reported previously (Mathew et al 1999b), a number of factors were significantly correlated with extrusion properties. In this study, the most predominate was corn moisture. The corn moisture content of the 16 samples varied between 9.5 and 13.5% and correlated significantly with bulk density (r = 0.86, P < 0.0001) (Fig. 1); breaking strength (r = 0.84, P < 0.000l, data not shown); volumetric expansion index (VEI) (r = –0.84, P < 0.0001) (Fig. 2); SME (r = –0.79, P < 0.0005) (Fig. 3); and degree of cook (r = –0.66, P < 0.0074) (Fig. 4). The effect of corn moisture was so large that it obscured the effect of cultivar and location.

During extrusion processing, moisture was added at the preconditioner to compensate for differences in the original moisture content of the corn samples. Thus, a constant flow rate of dry material was maintained through the extruder. However, the data shows that this compensation did not account for the variations caused by the differences in the original moisture content of the corn, otherwise corn moisture would not correlate with the extrusion properties. No significant correlation occurred between the corn moisture and properties of the corn curl extrudate (r = 0.15 for moisture vs. VEI). The corn curl formulation was essentially corn grits and water. Thus, the other ingredients (base mix) added to the ground corn in the pet food formulation clearly played a significant role in the effect of corn moisture.

Effect of Water Addition on Pet Food Extrusion

The effect of water addition on the bulk density of wet extrudate is shown in Fig. 5. Significant differences occurred in the wet extrudate bulk densities depending on whether water was added in the preconditioner or at the extruder barrel. In the most common dough moisture range (21.5–23.5%), water addition in the preconditioner produced increased expansion (shown by lower bulk densities) compared with water addition in the extruder barrel. At lower moisture levels (>21.5%), the moisture had no effect.

Effects of Retention Time in Preconditioner on Pet Food Extrudate

At a constant retention time of 106 sec, the corn with a moisture content of 11.2% produced extrudates with a bulk density of 342 g/L. An increase in the retention time to 184 sec caused a decrease in the bulk density (showing increased expansion) of the wet extrudates to 324 g/L.

After preconditioning, the corn grits (100% over 24-wire mesh) and base mix (100% through 24-wire mesh) were sieved, and their moisture contents determined. The increase of moisture content was much higher in the base mix than in the corn. About 75% of the moisture (water + steam) added in the preconditioner was absorbed by the base mix, and the remainder presumably by the corn.

However, careful examination of the sieved, preconditioned corn grits showed agglomerated base mix (observed as small balls) along with corn grits. Also, many of the corn grits were coated

TABLE I
Corn Hybrids, Growth Locations, Proximate Analyses, Test Weight, and Density

Hybrid No.	Growth Location	Moisture (%)	Fat (%)	Protein (%)	Starch (%)	Test Wt. (lb/bu)	Abs. Density (g/cm^3)
3162	Johnston	10.2c[a]	4.72ef	9.3d	71.39d	61.25e	1.31bc
3162	Creston	11.2b	4.61h	9.2d	71.04f	63.50a	1.32ab
3245	Doniphan	13.6a	4.64hg	10.1a	70.37j	65.35a	1.32a
3394	Johnston	11.6b	4.10k	7.6j	71.76c	60.70f	1.27hi
3394	Creston	11.1b	4.43i	9.4c	70.48i	62.05c	1.30c–e
3394	Nevada	9.7d	4.28j	8.0i	72.80a	60.35g	1.27hi
3394	CIL	13.5a	4.24j	8.9f	70.70k	60.35g	1.29e–g
3489	Johnston	10.3c	5.08b	9.1e	68.75n	59.99h	1.28fg
3489	Creston	11.3b	4.74ef	10.0b	69.20m	61.65d	1.29def
3489	Nevada	9.5d	5.18a	8.6g	70.76kg	59.60i	1.26i
3525	Johnston	11.4b	4.84d	8.9f	70.05k	59.85hi	1.3cd
3525	Nevada	9.6d	4.69fg	8.1h	72.06b	60.55fg	1.28gh
3563	Johnston	10.4c	5.08b	8.1k	69.87l	62.35b	1.30c–e
3563	Nevada	9.6d	5.00c	7.6j	71.26e	60.75f	1.28fg
3769	Algona	11.6b	4.78de	9.2d	69.86l	58.75j	1.26i
3394-E	CIL	13.5a	4.46i	9.3d	70.86g	62.55b	1.32ab

[a] Values followed by the same letter in the same column are not significantly different (P < 0.05).

TABLE II
Corn Hybrid, Growth Locations, and Kernel Characteristics[a]

				Screen Diameter			
Hybrid No.	Growth Location	HKW (g)	Kernel Width (cm)	S24 24/64" (%)	S19 19/64" (%)	S16 16/64" (%)	Particle Size (GDM)
3162	Johnston	29.15k[b]	7.4gh	1.0hi	58.5g	35.5b	387
3162	Creston	38.85a	7.7fg	2.0gh	74.5d–f	21.5c	403
3245	Doniphan	39.05a	8.3b–c	8.0c	84.0ab	6.0g	405
3394	Johnston	32.30f	8.6ab	6.0de	79.5b–d	13.5de	361
3394	Creston	37.05b	8.2c–e	11.5a	76.0d–f	11.5ef	393
3394	Nevada	30.65g	8.2c–e	5.5e	74.0ef	17.5cd	398
3394	CIL	36.55bc	8.5abc	7.0cd	84.0ab	8.0fg	365
3489	Johnston	34.20e	7.9ef	4.0f	85.5a	9.5e–g	366
3489	Creston	35.50g	8.5a–c	8.0c	82.0a–c	7.0fg	419
3489	Nevada	33.80e	8.5a–c	2.0gh	78.5c–e	17.5cd	402
3525	Johnston	28.95h	8.7a	2.0gh	72.0f	21.0c	391
3525	Nevada	29.45h	7.9ef	3.0fg	72.5f	21.5c	357
3563	Johnston	25.65i	7.1h	0.0i	28.5h	62.5a	400
3563	Nevada	24.65j	7.1h	0.0i	30.5h	60.5a	372
3769	Algona	31.15g	8.2bc–e	9.5b	77.0c–f	11.5ef	368
3394-E	CIL	36.20c	8.1de	4.0f	76.5d–f	17.5cd	368

[a] HKW = 100 kernel weight; GDM = geometric mean diamter.
[b] Values followed by the same letter in the same column are not significantly different (P < 0.05).

with base mix. These observations indicate that part of the sieved, preconditioned grits was contaminated with base mix. This may account for the observed increase in the moisture content of corn grits after preconditioning. Thus, the corn grits may not have actually gained any moisture during preconditioning. This indicates that moisture addition (compensating for original corn moisture differences between different treatments) at the preconditioner was not effective for pet food extrusion.

Effect of SME on Bulk Density of Pet Food Extrudate

An increase in SME caused a significant decrease in the bulk density of wet extrudates for all four treatments. At constant SME, significant differences occurred among the four samples that varied in moisture content (Fig. 6). Thus, this study clearly showed that the differences in samples moisture cannot be compensated for merely by maintaining a constant SME.

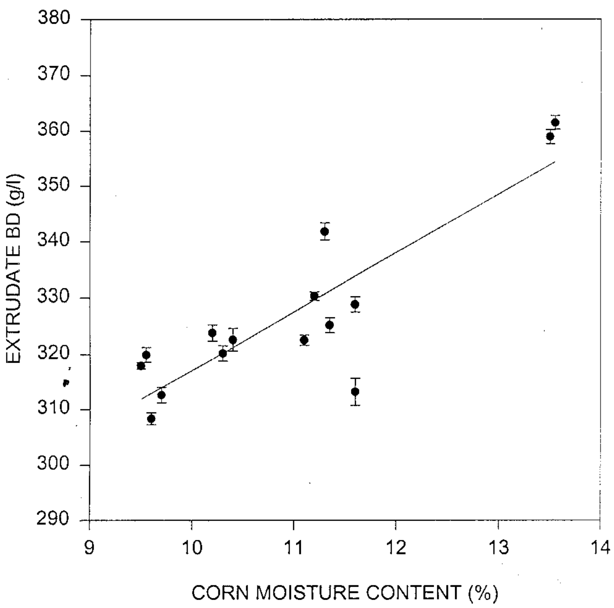

Fig. 1. Effect of corn moisture content on bulk density (BD) of pet food extrudates. $r = 0.82$. Error bars indicate standard error within batch.

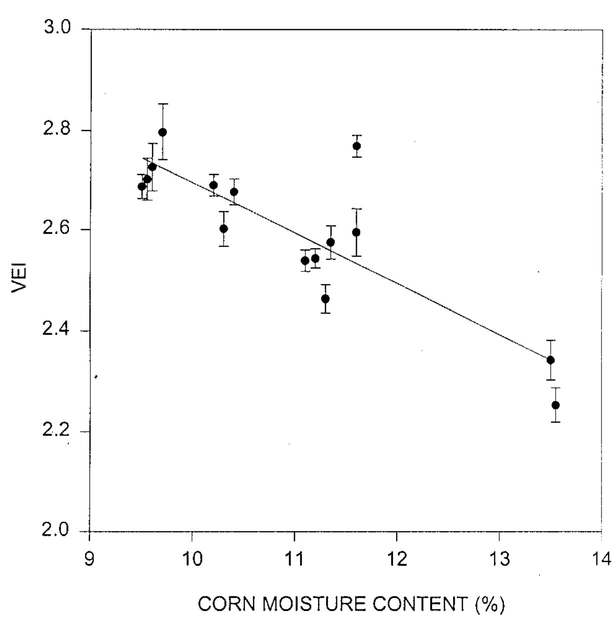

Fig. 2. Effect of corn moisture content on volumetric expansion index (VEI) of pet food extrudates. $r = 0.72$. Error bars indicate standard error within batch.

CONCLUSIONS

Corn moisture varied from 9.5 to 13.5%. Although the effect of differences in moisture were compensated for at the extruder, corn moisture was still correlated highly to most extrusion properties. Water addition at the preconditioner was more effective than addition at the extruder. Longer retention times in the preconditioner also improved expansion.

Addition of water to corn-premix mixtures showed that the water was absorbed essentially by the premix. Thus, differences in corn moisture cannot be compensated for by adding water at the extruder barrel. In addition, it was shown that differences in moisture cannot be overcome by controlling SME.

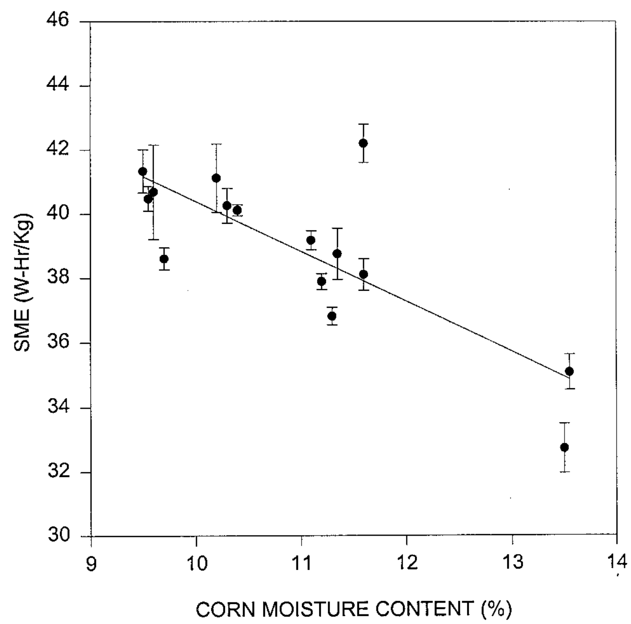

Fig. 3. Effect of corn moisture content on specific mechanical energy (SME) during processing of pet food extrudate. $r = 0.67$. Error bars indicate standard error within batch.

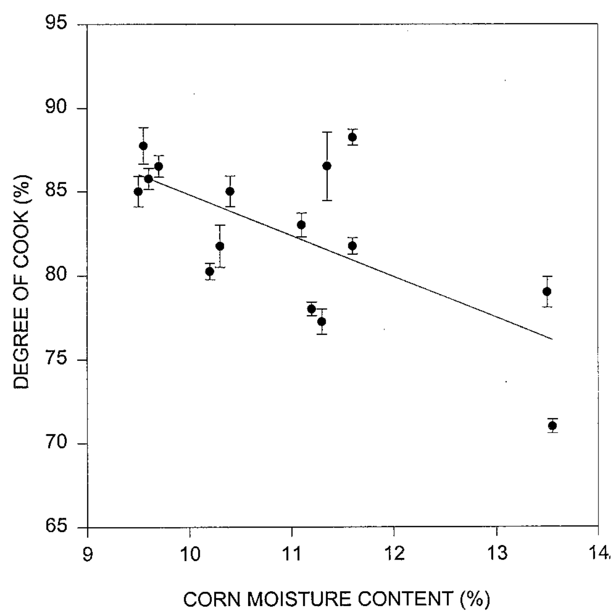

Fig. 4. Effect of corn moisture content on degree of cook of pet food extrudate. $r = 0.63$. Error bars indicate standard error within batch.

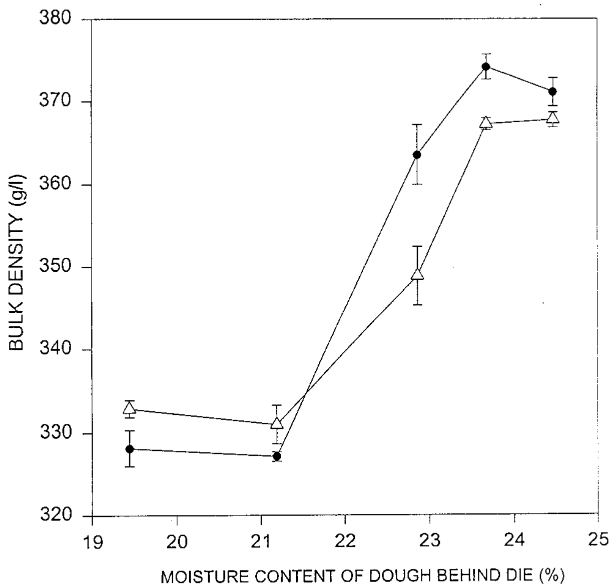

Fig. 5. Effect of meal (corn + base mix) moisture contents on wet extrudate bulk densities of pet food extrudates. Different moisture contents of meal were simulated by changing water addition in preconditioner (Δ) or extruder barrel (●). Error bars indicate standard error within batch.

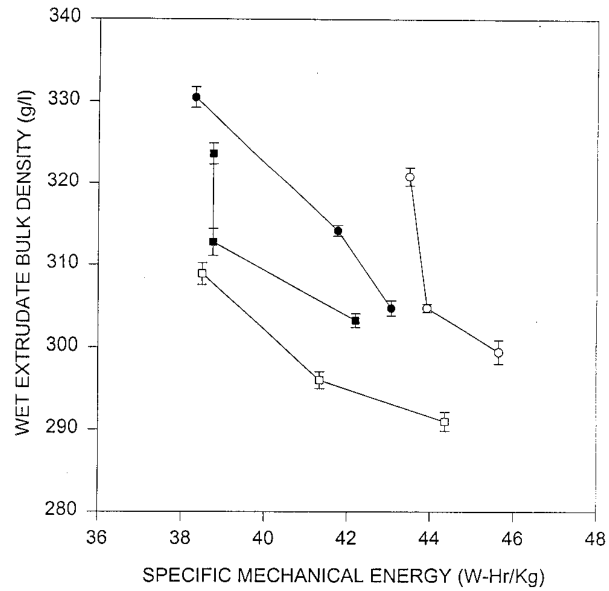

Fig. 6. Effect of specific mechanical energy on bulk density of wet pet food extrudate. Hybrid 3162 grown at Creston, IA (○, 11.2% moisture) and Johnston, IA (●, 10.2% moisture) and hybrid 3394 grown at Creston, IA (□, 11.1% moisture) and Nevada, IA (■, 9.7% moisture). Error bars indicate standard error within batch.

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