STUDIES ON WASTE POTATO STARCH AND CORN IN UREA-CONTAINING LIQUID SUPPLEMENTS USING *IN VITRO* RUMEN FERMENTATION[1]

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ABSTRACT

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Hydrothermally processed starch:urea mixtures employed in urea-containing liquid supplements were shown to improve nitrogen (N) use through *in vitro* rumen fermentation. Starch sources used were potatoes and corn. The starch source was blended with feed-grade urea (45% N) and water in a specific starch source:urea ratio, then hydrothermally processed. Phosphoric and propionic acids were added to lower pH and to act as an antifungal agent, respectively. *In vitro* microbial protein synthesis showed the 1.63:1 potato-based supplement on an as-is basis had more protein synthesized ($P < 0.05$) than did either the 1.90:1 potato- or 1.83:1 corn-based liquid supplement. However, on a dry basis, the corn-based supplement had more protein synthesized ($P < 0.05$) than either of the potato-based supplements. Compared with a 1.83:1 corn-based supplement, a 1.83:1 potato product performed equally well or better, based on microbial protein synthesized.

Liquid supplements are used to supply energy and nitrogen (N) in ruminant rations. Normally they are produced from a liquid vehicle (molasses, fermentation liquors, or distiller's solubles) mixed with nonprotein nitrogen (NPN), water, and phosphoric acid. Urea is a common source of NPN used in liquid supplements.

With urea in a ruminant ration, a major dietary requirement is the correct carbohydrate source to supply carbon skeletons and energy for synthesis of microbial protein. Studies indicate that cellulose is degraded too slowly, while mono- and disaccharides are fermented too rapidly to promote the most effective use of urea. Previous work indicates that starch is superior to molasses in providing the carbon skeletons (1).

Ammonia toxicity may occur when ruminants are fed high-urea diets. The ammonia is produced in the rumen upon hydrolysis of urea by urease (2). Urea-carbohydrate complexes decrease the rate at which ammonia is released (3–5). Hatch and Beeson (6) have suggested that a combination of molasses and starch as carbohydrate sources improves use of urea. Meyer *et al.* (7) showed that, compared with unprocessed grain-urea mixtures, incorporating urea with expanded grain lowered rumen ammonia concentration 50% and increased bacterial N 50%.

A liquid supplement[4] has been developed to improve N and carbohydrate use by ruminants by blending molasses with a hydrothermally processed corn:urea slurry. Studies reported here were to determine the feasibility of using potato starch waste[5] as the carbohydrate source in this liquid supplement.

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MATERIALS AND METHODS

Study I was conducted to compare corn- and potato-based liquid supplements with different starch source:urea ratios. The potato-based supplement was produced with 1.63:1 and 1.90:1 starch source:urea ratios; ratio of the corn-based supplement was 1.83:1 (Table I).

Medium grind corn was further ground through a Micro-Bud[6] micropulverizer before blending with feed-grade urea (45% N) in a 1.83:1 ratio calculated on an as-is basis. Water was added to form a slurry. The corn:urea slurry was hydrothermally processed at 149°C and 40 psig. Cane molasses was added to adjust the protein equivalent to approximately 30%. The slurry was cooled to 60°C before α-amylase (derived from *Bacillus subtilis*) was added to decrease the supplements' viscosity. When a viscosity approximately equal to 600 cP units was reached, enzyme activity was terminated with phosphoric acid (1.0% by wt). After the supplement cooled to 40°C, propionic acid (0.5% by wt) was added to inhibit mold growth.

The potato starch used was a semisolid, paste-like material. On an as-is basis, it contained 45% dry matter, 0.23% protein, 0.05% ash, no measurable ether extract or crude fiber, and 44.72% N-free extract (NFE) determined by difference.

Potato-based liquid supplements were produced as described for the corn samples except that water in the potato starch was used as part of the slurry. The 1.63:1 and 1.90:1 potato-starch urea ratios are calculated on a 90% dry matter basis.

Study II was conducted to compare corn- and potato-based liquid supplements formulated with a 1.83:1 starch source:urea ratio. The ratio was calculated on a 90% dry matter basis (Table I). Processing techniques were the same as in Study I.

Protein equivalent was determined by the Kjeldahl Method (N $\times$ 6.25); moisture content, by oven drying at 130°C 1 hr (8). Starch damage was estimated

[6]Metals Disintegrating Company, Pittsburgh, PA.

TABLE I
Formulas for Potato- and Corn-Based, Hydrothermally Processed Liquid Supplements

Ingredient %	Starch Source:Urea Ratio 1.83:1	1.83:1	1.90:1	1.63:1
Corn	18.12	...	...	...
Potato starch waste 90% dry matter	...	18.12	20.94	17.91
Urea	9.90	9.90	11.04	11.00
Cane molasses	12.94	12.94	31.04	38.50
Water	57.53	57.53	35.47	31.08
Phosphoric acid	1.00	1.00	1.00	1.00
Propionic acid	0.50	0.50	0.50	0.50
Enzyme, α-amylase	0.01	0.01	0.01	0.01

by enzyme hydrolysis with β-amylase and then measuring reducing sugars with ferricyanide (9). Results are reported as maltose equivalent. Barr's (10) *in vitro* rumen-fermentation technique was used to determine microbial protein synthesized.

RESULTS AND DISCUSSION

The potato starch waste had unique processing characteristics. It was a solid material with a dry matter content of 45%. French (11) reported that, when water was used as the solvent, urea would break some hydrogen bonding in starch. When dry urea was mixed with potato starch waste, viscosity decreased extensively, which permitted a higher level of solids to be hydrothermally processed than could be achieved with corn as the starch source. Effects of the carbohydrate sources on dry matter content of hydrothermally processed liquid supplements are shown in Table II. Potato-based liquid supplements were produced containing more than 50% dry matter when crude protein was adjusted to 30% with molasses, whereas the corn-based supplement contained 34% dry matter after adjustment with molasses. Dry matter of the final products varied with different carbohydrate sources due to the handling properties of the two starch sources. This allowed for the different levels of solids that could be hydrothermally processed.

Table II shows pH, dry matter, protein equivalent, and maltose values found in Study I. Protein of samples ranged from 29 to 30% on an as-is basis. On a dry basis, protein was 55% for potato-based supplements, compared with 86% for corn-based supplements. Samples containing different starch sources and starch source:urea ratios varied widely in maltose equivalents. The 1.63:1 ratio for potato-based supplement had 380 mg maltose/g dry matter; the 1.90:1 ratio, 327 mg maltose; the corn-based supplement, 185 mg maltose. Variations in maltose resulted largely from the variations in amount of molasses required to adjust the protein equivalent of the cooked starch:urea material to 30%. Therefore, maltose values indicate the amount of readily available carbohydrate per gram dry matter of liquid supplement. The pH, regardless of starch origin or starch:urea ratio, ranged from 3.8 to 4.1, a small variation (Table II).

TABLE II
Study I: Comparisons of Potato- and Corn-Based Supplements with Unequal Starch Source:Urea Ratios[a]

Starch Source	Ratio of Starch Source to Urea	pH	Dry Matter %	Crude Protein[b] %	Maltose[b] mg/g
Potato	1.63:1	4.06	53.30	55.58	380
Potato	1.90:1	3.78	50.48	59.20	327
Corn	1.83:1	3.84	33.82	86.49	185

[a]Values are averages of duplicate sets.
[b]Dry weight basis.

Table III shows *in vitro* protein synthesis of liquid supplements produced with different starch sources. Data are presented on an as-is and dry basis. The statistical analysis of variance used a nested model to remove effects of samples within treatments from the error. Protein synthesis with the 1.63:1 potato-based supplement on an as-is basis was higher (approximately 15%) ($P < 0.05$) than with the 1.90:1 potato- or corn-based supplements. The data suggest that, on an as-is basis, the 1.63:1 potato-based supplement would be best used by ruminants, but when data were corrected for dry matter, the results were reversed. Protein synthesis with the corn-based supplement was 25 to 30% higher ($P < 0.05$) than with 1.63:1 or 1.90:1 potato supplements. On a dry basis, the two potato-based supplements did not differ ($P < 0.05$). Differences between results of protein synthesis reported on an as-is and a dry basis were attributed to the total amount of cooked starch which was being supplied and the levels of molasses which were added to the supplements (Table I).

The purpose of Study II was to directly compare liquid supplements produced from the two starch sources. Formulas from Table I were used to hydrothermally produce both corn- and potato-based liquid supplements in 1.83:1 starch

TABLE III
Study I: *In Vitro* Protein Synthesis Comparison of Potato- and Corn-Based Liquid Supplements[a]

Starch Source	Starch Source:Urea Ratio	Control[a]	
		As-is %	Dry basis %
Potato	1.63:1	115.5*	72.5*
Potato	1.90:1	101.5	69.5*
Corn	1.83:1	100.0	100.0

[a]Potato *in vitro* values are reported as a percentage of the supplement containing corn. Results are based on two *in vitro* runs.

TABLE IV
Study II: Comparison of Potato- and Corn-Based Supplements with Equal Starch Source:Urea Ratios[a]

Starch Source	Starch Source: Urea Ratio	Dry Matter %	Protein[b] %	Maltose[b] mg/g	Control Protein Synthesis[c] %
Potato	1.83:1	39.4	69.29	597	106.5
Corn	1.83:1	36.5	76.89	469	100.0

[a]Values are averages of duplicate sets.
[b]Dry weight basis.
[c]Potato *in vitro* values are reported as a percentage of the supplement containing corn (control) and are based on two runs.

source:urea ratios. Samples of corn- and potato-based supplement were processed on different days. The analytical results are presented in Table IV. The average dry matter content of potato-based samples was 39.4%; corn-based samples, 36.5%. Difference in pH was small, regardless of starch source. Crude protein contents of samples ranged from 26.5 to 28% on an as-is basis.

Maltose data on Table IV show that potato-based samples had approximately 125 mg more maltose/g of dry matter than the corn-based supplement. The difference may have resulted from corn being approximately 77% starch, while potato starch was 99.4% starch on a dry matter basis. A second factor could be that potato granules may have been damaged more than starch in the corn, causing the potato starch granules to be more susceptible to β-amylase.

Table IV shows the *in vitro* protein synthesis results on a dry basis. The potato-based supplement synthesized a higher percentage of protein (average) than the corn-based supplement, but not significantly more ($P < 0.05$), so the hydrothermally processed potato supplement and the corn supplement performed equally.

CONCLUSIONS

The viscosity of the potato starch waste decreased extensively when blended with urea. That allowed a higher level of solids to be processed than achieved with corn-based supplements processed similarly.

The 1.63:1 potato-based supplement on an as-is basis synthesized more protein ($P < 0.05$) than either the 1.90:1 potato- or 1.83:1 corn-based liquid supplements. On a dry basis, the corn-based supplement synthesized more protein ($P < 0.05$) than either of the potato-based supplements. Comparison of a 1.83:1 corn-based supplement with a 1.83:1 potato supplement showed the potato product performed at least equal to, if not better than, the corn-based supplement in amount of protein synthesized. Maltose values were higher with potato- than with corn-based liquid supplements.

These data should be of value to both the livestock and potato industry. This product provides a supplement that incorporates an inexpensive energy source and helps relieve a waste disposal problem.

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