Effect of Additional Separation and Grinding on the Chemical and Physical Properties of Selected Corn Dry-Milled Streams[1]

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ABSTRACT

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Three streams of corn dry-milled products (corn grits, corn cones, and corn flour) from three different commercial corn dry-millers were further separated by particle size according to the major portion of each stream. They were separated into corn grits (1.190 and 0.841 mm), corn cones (0.595, 0.420, and 0.297 mm), and corn flour (0.297 and 0.210 mm). Besides separation, corn grits were also ground and then separated into ground corn grits (0.297 and 0.210 mm). The original streams, streams with additional separation, and streams with additional grinding were analyzed for protein content, ash content, crude fat content, and color properties. Duncan's significant difference tests ($P < 0.01$) showed that additional separation and grinding of the commercial corn grits, corn cones, and corn flour affected protein, crude fat content, and color parameter (L, a, and b) distribution of the products. The tristimulus parameters (L, a, and b) were good indicators of the protein content of the corn dry-milled streams studied.

The corn used for making breakfast cereal and puffed snacks is usually dry-milled. Most of the time corn dry-milling consists of four basic processes: removing foreign material from the corn, conditioning the corn kernel, separating the pericarp and the germ using degerminators, and, in some instances, grinding the endosperm. Size reduction is accomplished by running the endosperm into sets of roller mills that are connected to separator sieves or purifiers. Corn grits and corn meal are primarily produced in the early stages of grinding, whereas flour is primarily produced in the later stages of grinding (Alexander 1987). Corn flour that comes from the floury endosperm is called break flour, but if it comes from the horny endosperm it is called reduction flour. Break flour contains less protein than reduction flour (Alexander 1987).

Each corn cereal or corn snack product requires different corn dry-milled products with different particle sizes and different characteristics. For example, corn flakes require corn endosperm with a size of one half or one third of the whole endosperm after removing the germ and bran (Fast 1993), a product called "flaking grits." Extruded gun-puffed cereals, on the other hand, require corn flour as the raw material (Fast 1993). These different demands for corn dry-milling products of different particle sizes and from different parts of the kernel show the importance of the separation and size-reduction processes in producing various corn dry-milled products.

Different parts of a corn kernel endosperm have different proportions of horny and floury endosperm. These different parts have different physical and chemical properties. For example, in yellow corn, the horny endosperm has more carotenoids (74–86%), the source of yellow color in yellow corn, than the floury endosperm (9–23%) (Watson 1987c). The horny endosperm also has 1.5–2.0% more protein (Watson 1987b) and has a thicker protein matrix than the floury endosperm (Watson 1987a). The floury endosperm is softer and easier to break than the horny endosperm. With the same amount of grinding, the floury endosperm has smaller particle size than the horny endosperm. Parts of corn endosperm with more floury endosperm have lighter color when compared with the parts that have more horny endosperm. Different proportions of horny and floury endosperm therefore produce different corn dry-milling streams with different characteristics after the separation and grinding processes. Thus, it is important to know what is the impact of some dry-milling steps on specific product streams. Therefore, the objective of this study was to evaluate the effects of additional separation and grinding on the chemical and physical characteristics of selected streams of the corn dry-milling process.

MATERIAL AND METHODS

Raw Materials

In this study, commercially dehulled and degermed yellow corn dry-milling streams were supplied by three different firms referred to as sources 1, 2, and 3. Each source supplied corn grits, corn cones, or corn meal, and corn flour. Particle size distribution and diameter definition of each stream was analyzed using the ASAE sieving method (ASAE 1989) with a Ro-tap shaker and sieving screens (W.S. Tyler, Mentor, OH) for 10 min.

Stream Separation

The separation of each stream was based on the major portion of the particle size distribution of the stream. Table I shows the selected streams and their size. A detailed particle size distribution of the original stream is tabulated in Jamin (1996). Samples used in this study were segregated from the top of the desired sieves. Corn grits from sources 1, 2, and 3 consisted of 18–26% corn grits (1.190 mm diameter) and 47–65% corn grits (0.841 mm diameter). The fraction segregated from corn grits were overs from the 16-mesh (1.190 mm diameter) and overs from the 20-mesh (0.841 mm diameter). The corn cones segregated fractions were overs from the 30-mesh (0.595 mm diameter), overs from the 40-mesh (0.42 mm diameter), and overs from the 50-mesh (0.297 mm diameter) because the corn cones mainly consisted of 7–30% 0.595 mm diameter, 24–50% 0.420 mm diameter, and 24–43% 0.297 mm diameter. The corn flour, mainly consisted of 43–55% 0.210 mm diameter and some corn flour of 0.297 mm diameter, thus it was segregated into overs from the 50-mesh (0.297 mm diameter), and overs from the 70-mesh (0.21 mm diameter).

Additional Grinding

Besides separation, corn grits were also ground and then separated into corn grits overs from the 50-mesh (0.297 mm diameter) and overs from the 70-mesh (0.210 mm diameter) by using a high-speed flour mill (Magic Mill III, Salt Lake City, UT) (Table I). There were a total of 12 different streams from sources 1 and 2, and 11 streams from source 3 (Table II). Streams are identified here by the average diameter according to Table I.

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Color Tests

Color tests were performed by using a colorimeter (HunterLab model A60-1005-654, Hunter Associates Laboratory, Reston, VA). Each sample was ground to less than U.S. Sieve No. 40 (0.420 mm) and larger than U.S. Sieve No. 140 (0.105 mm). Color tests on each sample were repeated at least twice.

Proximate Analysis

Each corn dry-milling stream and the segregated and additionally ground samples were analyzed for chemical properties such as protein, moisture, ash, and oil content using the Approved Methods (AACC 1995). For the protein analysis, each sample was replicated four times; for moisture, ash, and oil, each sample was replicated three times.

RESULTS AND DISCUSSIONS

Chemical Analysis

The ash content of all corn grits, corn cones, and corn flour are tabulated in Table II. Ash, which is basically mineral, is richly found in corn germ (Watson 1987a). However, since all samples in this study were degermed corn products, the ash content of all the samples was very low when compared to that of a whole kernel sample.

The ash content of the original corn grits from source 1 was significantly higher than corn cones and corn flour from source 1. Unlike source 1, corn flours from sources 2 and 3 have the highest ash content value when compared to other original milled streams. This might be caused by the difference in the way the suppliers grind the corn and the raw material used. For all sources, there are significant differences ($P < 0.01$) in ash content between the original corn flour and at least one stream of corn flour with additional separation and between the original corn grits and at least one stream of corn grits with additional grinding. In source 2, additional grinding of corn grits caused the concentration of ash content in the streams with bigger particle size (corn grits 0.297 and 0.210 mm).

Crude fat is found predominantly in corn germ (excluding high-oil corn hybrids). However, because all samples in this study were degermed corn products, the crude fat contents of all the samples were very low. The crude fat content of an "average" commercial whole kernel of corn is 4.4% db (Watson 1987a) excluding high-oil corn hybrids. The corn endosperm itself only has 0.80% db crude fat content (Watson 1987a). All of the grits in this study had an average crude fat content <1% db. In Table III, corn grits 1.190 mm from source 1 had the highest crude fat content when compared with other grits from source 1, perhaps this was due to the presence of some germ particles. Corn grits with additional separation had a crude fat content significantly different from that of the original corn grits. In source 1, additional separation also caused a fat segregation by having the larger grits of source 1 (1.190 mm) with more crude fat than the smaller grits. However, additional grinding and separation of corn grits caused the crude fat content of corn grits 0.297 mm to be significantly lower than that of corn grits 0.210 mm. The average crude fat content of corn grits 0.297 mm and corn grits 0.210 mm, which represent ≈71% of the total ground corn grits, are higher than that of the original corn

TABLE I
Selected Corn Dry-Milled Streams for Study

Milled Streams	Source	Segregated/Ground Corn Overs	Nominal Sieve Opening (mm)
Corn grits	1, 2, 3	16-mesh	1.19[a]
	1, 2, 3	20-mesh	0.841[a]
	1, 2, 3	50-mesh	0.297[b]
	1, 2, 3	70-mesh	0.210[b]
Corn cones	1, 2, 3	30-mesh	0.595[a]
	1, 2, 3	40-mesh	0.420[a]
	1, 2, 3	50-mesh	0.297[a]
Corn flour	1, 2	50-mesh	0.297[a]
	1, 2, 3	70-mesh	0.210[a]

[a] Separated streams.
[b] Additionally ground streams.

TABLE II
Ash Content (%db) of Corn Grits, Corn Cones, and Corn Flour[a]

Sample	Source 1	Source 2	Source 3
Corn grits	0.42b	0.30f	0.33d,e
1.190 mm[b]	0.53a	0.34f	0.33d,e
0.841 mm[b]	0.39b,c	0.40e	0.33d,e
0.297 mm[c]	0.35c,d,e	0.46c,d	0.24f
0.210 mm[c]	0.37b,c,d	0.48c,d	0.33d,e
Corn cones	0.31d,e,f	0.39e	0.32d,e
0.595 mm	0.28e,f,g	0.49c	0.31e
0.42 mm	0.26f,g,h	0.40e	0.35c,d,e
0.297 mm	0.33c,d,e	0.39e	0.40c
Corn flour	0.21h	0.44d,e	0.47b
0.297 mm	0.30d,e,f,g	0.64b	na[d]
0.210 mm	0.23g,h	0.75a	0.90a

[a] Values followed by the same letter in the same column or from the same source are not significantly different ($\alpha = 0.01$).
[b] Corn grits with additional separation.
[c] Corn grits with additional grinding.
[d] Data is not available because of different particle size distribution in corn flour from source 3.

TABLE III
Crude Fat Content (%db) of Corn Grits, Corn Cones, and Corn Flour[a]

Sample	Source 1	Source 2	Source 3
Corn grits	0.49c	0.92d	0.56b
1.190 mm[b]	1.08a	0.42g	0.39c
0.841 mm[b]	0.65b	0.58e,f	0.34c,d
0.297 mm[c]	0.51c	1.02b,c	0.31c,d
0.210 mm[c]	0.69b	1.12b	0.65a,b
Corn cones	0.36d	0.86d	0.68a,b
0.595 mm	0.48c	0.60e	0.38c
0.42 mm	0.47c	0.62e	0.30c,d
0.297 mm	0.50c	0.58e,f	0.38c
Corn flour	0.34d	1.38a	0.71a
0.297 mm	0.39d	1.14b	na[d]
0.210 mm	0.35d	0.47f,g	0.20d

[a] Values followed by the same letter in the same column or from the same source are not significantly different ($\alpha = 0.01$).
[b] Corn grits with additional separation.
[c] Corn grits with additional grinding.
[d] Data is not available because of different particle size distribution in corn flour from source 3.

TABLE IV
Protein Content (%db) of Corn Grits, Corn Cones, and Corn Flour[a]

Sample	Source 1	Source 2	Source 3
Corn grits	5.61b	6.05d	5.95f
1.190 mm[b]	5.73b	6.04d	6.13d,e,f
0.841 mm[b]	5.52b	6.10c,d	6.01e,f
0.297 mm[c]	6.38a	6.34a	6.67a
0.210 mm[c]	5.62b	6.17b,c	5.99e,f
Corn cones	4.90d,e	5.66f	6.43b,c
0.595 mm	5.30c	6.24a,b	6.45b
0.42 mm	4.98d	5.69f	6.26c,d
0.297 mm	4.72e	5.51g	6.65a
Corn flour	3.26g	5.01i	5.60g
0.297 mm	3.49f	5.90e	na[d]
0.210 mm	3.27g	5.32h	6.18d,e

[a] Values followed by the same letter in the same column or from the same source are not significantly different ($\alpha = 0.01$).
[b] Corn grits with additional separation.
[c] Corn grits with additional grinding.
[d] Data is not available because of different particle size distribution in corn flour from source 3.

grits (Jamin 1996). Therefore, it is possible that 29% of the ground grits >0.297 mm and <0.210 mm have less crude fat content.

Unlike source 1, in source 2 the corn grits with the highest crude fat content were the corn grits 0.210 mm instead of the corn grits 1.190 mm. In the source 2 samples, additional separation and grinding caused the smaller grits to contain more crude fat than the bigger grits. When the original corn grits were sieved to prepare for corn grits 1.190 mm and 0.841 mm, the smaller grits that possibly have had more crude fat in the fraction were discarded. Therefore, corn grits 1.190 mm and 0.841 mm had less crude fat than the original stream. When the corn grits were ground to become corn grits 0.297 mm and 0.210 mm, the part of the grits with high crude fat and ash content were broken into 0.297 mm or 0.210 mm, but not smaller than that. Therefore, for source 2 the ground corn grits (0.297 mm and 0.210 mm) had more crude fat than did the separated grits (1.190 mm and 0.841 mm) (Table III).

Similar to source 2, in source 3 corn grits 1.190 mm, 0.841 mm, and 0.297 mm had significantly less crude fat than the original corn grits. The grits from source 1 that contain high crude fat content might be broken into sizes <0.210 mm, whereas the grits from sources 2 and 3 with high crude fat did not break so easily and had particle sizes in the range of 0.297–0.210 mm. Additional separation of corn grits caused significant differences in crude fat content between the original corn grits and the separated corn grits. This was consistent throughout all three products (sources 1, 2, and 3). The differences between source 1 and sources 2 and 3 could have been caused by differences in corn blends, dry-milling process flow, or the degerminator used. The type of degerminator used in a milling process could affect the crude fat content of the product because most of the crude fat is concentrated in the germ. Sources 2 and 3 were larger corn dry-milling facilities that use a Beall degerminator on the germ removal process of the germ, whereas source 1 is a smaller corn dry-milling company that used a Buhler impact degerminator to remove the corn germ.

Table III also shows the crude fat content of corn cones streams from all three different sources. Regardless the crude fat content, each original corn cones from all three different sources have significantly different ($P < 0.01$) crude fat content when compared with the corn cones with additional separation. The higher values of crude fat content in corn cones 0.595 mm, 0.420 mm, and 0.297 mm in source 1 as compared with that of the original corn cones could have resulted from the separation process. The sieving process of the corn cones causes the finer material that had less crude fat content to be segregated from the separated samples (corn cones 0.595 mm, 0.420 mm, and 0.297 mm). Therefore, the crude fat content of each separated sample was higher than that in the original corn cones. However, the opposite occurred in sources 2 and 3. Evidently, the separation process caused source 2 and 3 streams with high crude fat content to be segregated. Thus, the separated corn cones (0.595 mm, 0.420 mm, or 0.297 mm) from sources 2 and 3 had significantly less crude fat content than the original corn cones.

In Table III, corn flour from source 2 has the highest crude fat content when compared with the other sources. There are significant differences among corn flour and corn flour with additional separation (corn flour 0.297 mm and 0.210 mm) in sources 2 and 3. For source 1, however, there is no significant difference in crude fat between corn flour and corn flour with additional separation. Corn flour 0.210 mm from sources 2 and 3 had significantly less crude fat content when compared with the original corn flour stream. These results show that separation and grinding process could affect the crude fat content of corn dry-milled streams. These crude fat differences in the streams could influence the finished product. In this study, separation and grinding processes have significant effects in producing a lower fat food product.

The ash and crude fat content (Tables II and III) of corn grits, corn cones, and corn flour from source 1 at the same particle size (0.297 mm) have a decreasing behavior as we move from corn grits, corn cones, and corn flour. However, there is no significant difference ($P < 0.01$) in ash content among the three samples. The ash and crude fat content of corn cones 0.297 mm from source 2 is lower than that of corn grits 0.297 mm and corn flour 0.297 mm from the same source. This behavior is different than source 1 samples. This different behavior of source 2 could be caused by difference in corn blend, difference in part of corn kernel, or difference in corn dry-milling degermination process previously mentioned. For source 3, the crude fat and ash content of corn cones 0.297 mm were higher than that of the corn grits 0.297 mm, although the protein content was similar.

Because the protein content in horny endosperm is greater than in floury endosperm (Watson 1987a), corn grits 1.190 mm from source 1 could have contained more horny endosperm than corn grits 0.841 mm (Table IV). Because the floury endosperm is softer and easier to grind, it was reduced to smaller particles than the horny endosperm. Additional separation could have caused the floury endosperm to be eliminated from corn grits 1.190 mm and 0.841 mm. The elimination of smaller grits produced similar protein values for the corn grits 1.190 mm and 0.841 mm as compared with the original corn grits (Table IV). This also occurred in sources 2 and 3.

By additional grinding and separating corn grits into corn grits 0.297 mm and 0.210 mm, the floury endosperm that has less pro-

TABLE V
Color Analysis for the Samples from Sources 1, 2, and 3[a,b]

	L			*a*			*b*		
Sample	**1**	**2**	**3**	**1**	**2**		**1**	**2**	**3**
Corn grits	89.54c	84.81e	83.95c	0.18c–e	2.90a–c	2.91d	16.49d,e	23.37b	23.68f,g
1.190 mm[c]	87.92d	84.58e,f	84.19c	0.39b	3.05a,b	3.39c	17.38d	23.87b	25.23d
0.841 mm[c]	89.97c	85.17c–e	84.33c	0.06e	2.63b,c,d	3.23c	16.36d,e	22.04b,c	24.14e–g
0.297 mm[d]	85.43f	84.84d,e	81.45f	1.10a	2.86a–d	4.26b	23.47a	23.49b	26.99c
0.210 mm[d]	87.03e	85.94c	85.99b	0.27b–d	2.29d	2.45e	20.82b	22.54b	23.48g
Corn cones	89.62c	85.91c,d	79.52g	0.12d,e	2.57b–d	4.47a,b	14.88f–h	22.28b,c	28.04b
0.595 mm	87.56d,e	85.00c–e	84.50c	1.00a	2.87a–d	3.16c,d	18.70c	22.57b	24.52d–f
0.42 mm	89.38c	85.02c–e	84.55c	0.38b	2.83a–d	3.15c,d	15.91e,f	22.53b	24.59d,e
0.297 mm	89.23c	81.80g	79.33g	0.28b,c	3.36a	4.58a	15.36e–g	25.90a	29.29a
Corn flour	91.08a	88.24a	87.36a	–0.22f	1.23e	1.50g	13.10i	19.22d	20.39i
0.297 mm	90.41a,b	83.65f	na[e]	–0.21f	2.37c,d	na[e]	14.25g–i	23.65b	na[e]
0.210 mm	90.56a,b	86.97b	86.38b	–0.18f	1.49e	1.97f	13.92h,i	20.51c,d	22.32h

[a] Values followed by the same letter in the same column are not significantly different ($\alpha = 0.01$).

[b] *L*: black (0) to white (100); *b*: yellowness (+) and blueness (–); *a*: redness (+) and greenness (–).

[c] Corn grits with additional separation.

[d] Corn grits with additional grinding.

[e] Data is not available because of different particle size distribution in corn flour from source 3.

tein and a softer texture easily broke apart from the horny endosperm. Some of the floury endosperm was removed by the sieving process or stayed in the corn grits 0.210 mm because the particle size became smaller. Therefore, the protein content of corn grits 0.297 mm was significantly higher than corn grits 0.210 mm for all sources. Thus, the grinding and sieving processes at the levels studied segregate horny endosperm from floury endosperm. Since the horny endosperm has high protein content, this process could be used to prepare raw material to produce high protein corn products.

In sources 1 and 2, similar behavior could be seen in corn cones 0.595 mm and corn flour 0.297 mm which have more protein content than other corn cones streams or other corn flour streams. This also indicates the significant presence of horny endosperm. For sources 1 and 2, the larger particle size in the corn flour (0.297 mm) may have contained more horny endosperm than corn flour 0.210 mm, which resulted in the higher values for protein content. Based on the high values for protein content, corn flour from sources 2 and 3 may have contained reduction flour, which comes from the horny endosperm, whereas corn flour from source 1 mainly consists of break flour, which comes from the floury endosperm (Alexander 1987).

Comparisons between the protein content of corn grits, corn cones, and corn flour for source 1 samples of the same particle size (0.297 mm) indicated that the protein content decreases as the sample changes from corn grits to corn cones and to corn flour. However in source 2, the protein content of corn cones 0.297 mm is lower than corn flour 0.297 mm. In source 3, the protein content of corn grits 0.297 mm and corn cones 0.297 mm are similar to each other. These differences in protein content of the samples with the same particle size show that the source of the corn samples also determines the characteristics of the samples. At the same particle size, corn grits, corn cones, and corn flour have different protein contents because each sample has different proportion of horny and floury endosperm. The effect of the different degermination system used for the materials from sources 2 and 3 compared with source 1 deserves more study.

Color Analysis

The results of the color analysis for all samples are given in Table V using the tristimulus parameters *L, a,* and *b*. The *L* values in the table represent a range of color from black ($L = 0$) to white ($L = 100$). The *b* values represent yellowness ($+b$) and blueness ($–b$). The *a* values represent redness ($+a$) and greenness ($–a$).

As shown in Table V, all corn flour samples from source 1 had high *L* values for whiteness and low *b* values for yellowness when compared with all corn grits samples and all corn cones samples. The yellow color is caused by the presence of carotenoids. The horny endosperm contains more carotenoids (46–54%) than the floury endosperm (28–36%) (Weber 1987). Therefore, the color analysis results show that the corn grits and corn cones had more horny endosperm and less floury endosperm than corn flour. This behavior can also be seen in *L, a,* and *b* values of original streams (corn grits, corn cones, and corn flour) and streams with additional separation or grinding.

In source 1, there were significant differences in *L* and *a* values between the original corn grits and at least one stream of corn grits with additional separation (corn grits 1.190 mm) and corn grits with additional grinding (corn grits 0.297 mm). The *b* values of corn grits with additional grinding were significantly higher than that of the original corn grits. This also occurred with the original corn cones and at least one stream of corn cones with additional separation. The highest *b* value was consistent with the high protein content in corn grits 0.297 mm (Table IV).

Correlation analysis at $P < 0.01$ between the tristimulus parameters and the chemical properties of the source 1 samples were investigated. The protein content of the source 1 samples correlated negatively with the *L* value (–0.80) and correlated positively with the *a* value (0.75) and with the *b* value (0.82). These correlation results from source 1 show that the yellowness (*b*) and whiteness (*L*) could indicate the amount of protein in the samples because of the amount of horny and floury endosperm. Therefore, for this study, the yellowness of a sample indicates a high protein content, which also indicates a high content of horny endosperm because horny endosperm has higher protein content when compared with floury endosperm.

As expected, corn flour from source 2 had the highest *L* value and the lowest *a* and *b* values. On the other hand, corn cones 0.297 mm from source 2 had the lowest *L* value and the highest *a* and *b* values. Among corn grits samples, corn grits 0.210 mm had the highest *L* value and the lowest *a* value. However, there was no significant difference in *b* value among corn grits. Among the corn cones samples, corn cones 0.297 mm had the lowest *L* value and the highest *a* and *b* values. Among the corn flour samples, corn flour 0.297 mm had the lowest *L* value and the highest *a* and *b* values, which also indicates that corn flour 0.297 mm had more yellowness and less whiteness or lightness when compared with other corn flour. This could have been caused by the horny endosperm, which is harder to break and has larger particle sizes than that of the floury endosperm, which is easier to break and has smaller particle sizes.

The correlation analysis of source 2 samples had lower correlation coefficients between protein and the tristimulus parameters than did source 1, although it followed the same trend. The correlation coefficients (*r*) for source 2 samples between protein content and *L, a,* and *b* values were –0.38, 0.62, and 0.48, respectively.

The *b* value for corn cones 0.297 mm from source 3 was the highest among corn cones samples. This result is consistent with the high protein content of corn cones 0.297 mm from source 3 (Table IV). Results for source 3 samples were similar to those for source 1 samples regarding protein content and the *b* value. There were significant differences ($P < 0.01$) in *L, a,* and *b* values between the original corn grits and at least one stream of corn grits with additional grinding (corn grits 0.297 mm). Additional separation also affected corn cones streams and corn flour streams.

Correlation analysis results show that *b* and *a* values of source 3 samples were positively correlated to protein content ($r = 0.70$ and 0.79, respectively) and *L* value is negatively correlated to protein ($r = –0.71$). The *b* values of corn grits, corn cones, and corn flour for source 1 were lower than those for sources 2 or 3. This is consistent with the lesser amount of protein in source 1 than sources 2 and 3.

For all three sources, overall *a* and *b* values were positively correlated with protein content ($r = 0.77$ and 0.83, respectively), whereas *L* values were negatively correlated ($r = –0.77$) with protein content. Therefore, we could conclude that the tristimulus parameter could indicate the amount of protein content in the degermed corn dry-milled products.

CONCLUSIONS

For all sources, there were significant differences ($P < 0.01$) in crude fat content between the original corn grits and at least one stream of corn grits with additional separation. Significant differences ($P < 0.01$) in ash content, crude fat content, protein content, and tristimulus parameters *L* and *a* were also found between the original corn grits and at least one stream of corn grits that had additional grinding. For all sources, there were significant differences ($P < 0.01$) in crude fat content, protein content, and tristimulus parameters *L, a,* and *b* between original corn cones and at least one stream of corn cones that had additional separation. There were also significant differences ($P < 0.01$) in protein content between the original corn flour and at least one stream of corn flour that had additional separation. Additional separation and grinding of the commercial streams of corn dry-milling products affected the chemical properties (protein and crude fat content) and the color of the products. This separation and grinding process also affected the ash content of the streams, although not all of the sources show significant differences. Additional grinding and separation caused the concentrating of horny endosperm in the larger-sized corn grits streams (corn grits 0.297 mm). The results of this study proved that additional separation and additional grinding of selected streams of the corn dry-milling process, with uniform particle size, can yield products with different proximate composition. This different proximate composition could be more suited to specific composition requirements for determined applications of the milled products.

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LITERATURE CITATIONS

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