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Understanding Corn Variability

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Overview

Corn is the most common feed ingredient used in poultry nutrition. Maize contributes with up to 65% of the metabolizable energy and 20% of crude protein in poultry diets (Gehring *et al*., 2013; Dei, 2017). Its average nutritional value is well-known, but it is accepted that the variability in its composition and energy value is a very common issue with great impact on poultry performance and health (Cowieson, 2005; Gehring *et al*., 2013; Latham *et al*., 2016; Montanhini-Neto *et al*., 2017). Corn variability affects growth, feed conversion, flock uniformity, digestibility, AMEn, digesta viscosity, gut microbiota composition, intestinal health, and efficacy of exogenous enzymes (Latham *et al*., 2016; Williams *et al*., 2017; Cordova-Noboa *et al*., 2020, 2021 a, b; Franciele *et al*., 2021, Giacobbo *et al*., 2021; Melo-Duran *et al*., 2020, 2021a, b).

This presentation will address recent advances in understanding the effects of corn variability. Poultry nutritionists can either forget about the sources of corn variability, keep using the same average values, and deal with the multiple consequences that this variability brings in the final results. Alternative pathways are using NIRS calibration to predict corn AME and other nutrients before formulation and make adjustments to feed formulation (Latham *et al*., 2016; Montanhini-Neto *et al*., 2017) and creating strategies to reduce nutrient variability. There are significant differences among NIRS predictions depending on the method used to develop prediction calibrations. Careful selection and evaluation of the best NIRS calibrations are necessary. The reduction in nutrient variability of feed ingredients requires a better understanding of the parameters affected for each factor, determining key indicators, measuring them, and generating policies in corn production and processing that minimize the variability.

Variability in corn composition

In animal nutrition, corn tends to be categorized by test weight per bushel, physical appearance, crude protein content, and proximate analysis are used to estimate its energy values (Cowieson, 2005; Gehring *et al*., 2013). However, the accuracy in estimating those energy values is not always satisfactory due to the variability in nutrient and antinutrient content, the grain's physical properties, and the interactions among these factors (Gehring *et al*., 2013; Zuber and Rodehutscord, 2017). Consequently, the AMEn may vary by more than 400 kcal/kg among corn batches (Cowieson, 2005). However, the most common range of variation is near 100 to 150 kcal/kg (Latham *et al*., 2016; Williams *et al*., 2017; Cordova-Noboa *et al*., 2020, 2021b; Melo-Duran *et al*., 2021a, b)

The content of all nutrients or their availability to generate energy could be variable in corn depending on genetics, soils, water availability, environmental conditions, moisture level at harvest, drying temperatures, storage conditions post-harvest, time of storage, and particle size (Cowieson, 2005; Gehring *et al*., 2013; Cong et al., 2015; Melo-Durán *et al*., 2021b).

Variability is part of nature, and there is an inevitable proportion impossible to control. For example, the position of the kernel in the cob causes variation in the nutrient and NSP content (Melo-Durán *et al*., 2021b). Grains in the basal portion of the cobs have higher contents of crude protein, starch, and AME and lower NSP and soluble arabinose to xylose (AX) ratios than the grains produced in the 23% apical portion of the cob. This effect of position in the cob varies with genetic varieties (Melo-Durán *et al*., 2021b). The genotype and the location of the plantation also interact, generating more variation in all nutrient compositions (Cong *et al*., 2015). The content of some nutrients depends more on the location or origin of the corn grain than the genotype or the interaction of the two factors. Consequently, categorization of corn by origin and provider is important to reduce variability.

Like any other grain, corn contains NSP, which is lower than wheat or barley, but NSP has great variability among maize genotypes. Soluble NSP concentration and its composition have diverse effects, including changes in gastrointestinal viscosity and pH that could be negative for digestion, serve as the substrate for beneficial gut microbiota that produces short-chain fatty acids with positive effects for the bird host (Nguyen *et al*., 2021). In a recent study conducted by Melo-Durán *et al*. (2021b), with 16 corn hybrids, total NSP ranged from 55.6-81.3 g/kg, soluble NSP ranged from 1.0 to 8.5 g/kg, total AX ranged from 38.8 to 50.0 g/kg, and soluble

AX ranged from 2.2 to 5.3 g/kg. The soluble AX of some maize varieties could be similar to wheat promoting digesta and excreta viscosity issues. On the other hand, there are corn varieties with less variability in nutrient and NSP content. Consequently, a long-term goal could be to use corn breeding and genetic selection to minimize this variability in corn nutritional value and NSP content.

The variation in corn crude protein is close to 5%, but the variation in zein content is more important (Kljak *et al*., 2018). The starch content variability is around 2%, but the final amylose to amylopectin ratio (AM: AP) may play a bigger role in energy and nutrient availability for animals and poultry. The AM: AP ratios vary with genetics, the interaction between moisture at harvest and the drying temperatures, and storage time. Amylopectin is digested better than amylose because the latest can form a very compact physical structure that inhibits digestion. Protein and starch content and their properties affect the hardness or vitreousness of the endosperm kernel and the protein solubility (Cowieson, 2005; Gehring *et al*., 2013).

Variability in physico-chemical properties of corn

Maize vitreousness, the ratio of hard to soft endosperm, is related to starch properties and zein content and highly correlated (r = 0.87) with kernel density Kljak *et al*., 2018). More vitreous corn has higher amylose and zein content, and its starch granules are smaller and circular. However, the zein content and its interactions with starch contribute more to vitreousness than starch molecular properties (Kljak *et al*., 2018). Corn with high vitreousness generally has 20 to 30% higher phytate content. High vitreousness is correlated with reduced nutritional value for poultry (Kaczmarek *et al*., 2013). But the response may vary depending on many factors, especially corn genetics. Then vitreousness cannot be considered the best parameter for nutritional quality in poultry nutrition (Gehring *et al*., 2013) but plays a role in nutrient quality.

Vitreousness varies among corn hybrids and plantation locations. In one study conducted by Correa *et al*. (2002) to determine the relationship between corn kernel vitreousness and ruminal *in situ* starch digestibility, this research group determines the variability of vitreousness among corn hybrids planted in Brazil and the US. Vitreousness of the five mature Brazilian hybrids averaged 73.1% (range of 64.2% to 80.0%), while vitreousness of the 14 mature U.S. hybrids averaged 48.2% (range of 34.9% to 62.3%). In this study, the U.S. hybrids were predominantly dent-endosperm cultivars, while the Brazilian hybrids were flint or predominantly flint endosperm cultivars.

Another marker of corn nutritional value is the extractable salt-soluble protein content or protein solubility index (PSI) in 0.5*M* NaCl. The standard French Promatest method NF-V03-741 (AFNOR, 2008) can be used to determine PSI, and these values can be estimated with NIRS. The PSI varies 20% among corn samples from different locations. Melo-Duran *et al*. (2021) indicated a high (r =0.83) positive correlation between PSI and AME predicted by NIRS. The PSI is reduced by the thermal denaturation of corn proteins, especially when harvested at high moisture.

Effects of thermal processing in corn variability

Drying corn to 15-13% is necessary to store corn and avoid microbial degradation. Drying may occur naturally on the field at around 30 to 35 ºC (86 - 95 ºF), but more frequently has to be done with hot air dryers at temperatures higher than 100 ºC (> 212 ºF). Most of the time, corn is exposed for a few minutes to temperatures between 245 to 284 ºF (115 to 140 ºC). Thermal processing interacts with corn moisture at harvest. Kernels have an average of 35% moisture at maturity. Harvest generally starts when corn moisture has reduced to 24-22%, but harvest may occur earlier with higher kernel moisture due to weather conditions. Climate change is increasing the earlier harvest with higher moisture content. The higher the initial moisture, the more the negative impact of corn starch and protein physicochemical changes.

Drying at 120 ºC can cause more amylose within starch (25.5%) than drying at 35 ºC (21.5%) and increases the starch gelatinization linearly without observing significant differences among the three (35, 80, and 120 ºC) drying temperatures evaluated (Córdova-Noboa *et al*., 2021b). The increment in amylose content due to high drying temperature (120 ºC) in hard endosperm kernels was twice (21.3 to 26.7%) as much as the one observed in grains with average endosperm (21.7 to 24.2%). However, no changes due to drying temperatures were observed on resistant starch, and only a small difference was detected (P=0.08) between the corn hybrids with average-hardness endosperm (4.84%) and hard-endosperm (4.40 %).

The previous observations are just a few of the multiple impacts of drying temperatures in corn of different kernel hardness. In experiments conducted by Cordova-Noboa *et al*. (2020; 2021a, b), we concluded that hot air-drying at either 80 or 120 ºC decreased vitreousness, PSI, increased damaged starch, total and insoluble NSP, total and insoluble arabinoxylans, increasing the AX compared to drying grain at 35 ºC in a commercial hybrid with lower vitreousness (61.98 %). In the harder endosperm hybrid, higher drying temperatures decreased damaged starch content and increased the AX compared to drying at 35 ºC. However, when corn kernels with harder endosperm (63.61% vitreousness) were dried, no changes in vitreousness, PSA, and NSPs due to drying temperature were observed.

Effects on particle size post-grinding and pellet durability

The changes observed in chemical components had effects on the breakage susceptibility of corn kernels during harvest and grinding. We observed interactive effects of corn variety and drying temperature on the geometric mean of particle size (d_{gw}) (Figure 1) and its distribution (S_{gw}) (Figure 2) after milling in the hammer and roller grinders (Cordova-Noboa *et al.*, 2020). The d_{gw} was positively correlated (r = 0.69) with amylopectin and negatively correlated with AM:AP (r = -0.68) and damaged starch (r = - 0.65).

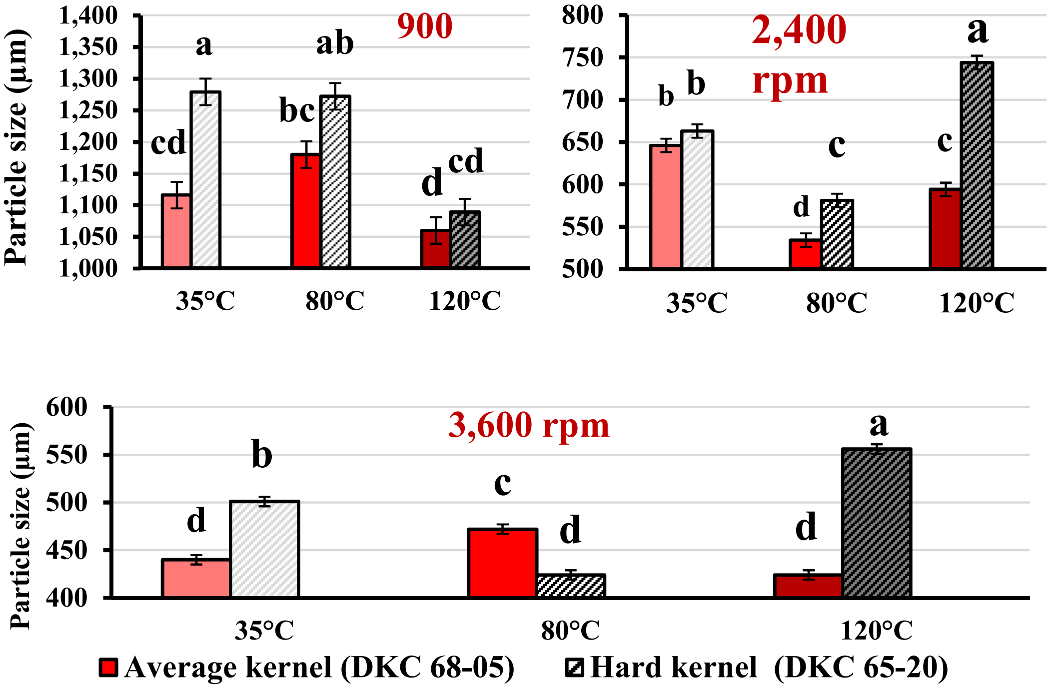


Figure 1. Effect of kernel hardness and drying temperature on particle size (D_{gw}) in a hammermill at 12-12 screen (4.76 mm) with 900, 2,400, and 3,600 rpm (Cordova-Noboa *et al.*, 2021a).

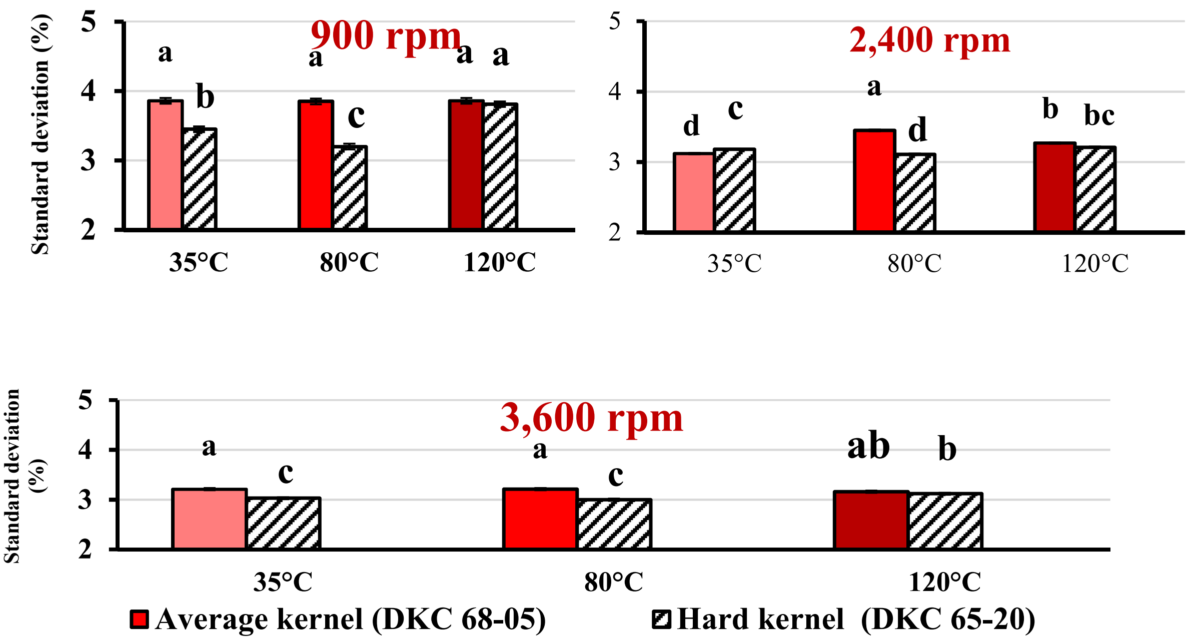


Figure 2. Effect of kernel hardness and drying temperature on standard deviation (Sgw) in hammermill at 12-12 screen (4.76 mm, US mesh 4) at 900, 2,400, and 3,600 rpm (Cordova-Noboa *et al.*, 2021a).

On the other side, the storage time decreased the d_{gw} independently of corn variety and drying temperature because some biochemical changes occur during storage. Additionally, the pellet durability index was better for diets with average kernel hardness and corn dried at 35°C than higher temperatures (Cordova-Noboa *et al.*, 2021a). Considering the well-known effects of these physical aspects of feed on poultry feed intake and intestinal physiology, corn variability also becomes important in this way.

All these effects in corn composition and particle size affected feed conversion ratio (FCR) in broilers (Figure 3) and feed intake mainly from 28 to 40 days of age (Cordova-Noboa *et al.*, 2021b). The interaction detected in FCR indicated that for average kernel hardness drying at higher temperatures improved utilization, while for hard endosperm, elevated temperatures worsen FCR. This result was related to higher AM: AP ratios and low damaged starch content in hard endosperm corn dried at 120 °C. Damaged starch increases water absorption capacity and susceptibility to erosion by α-amylase, ultimately improving starch digestion.

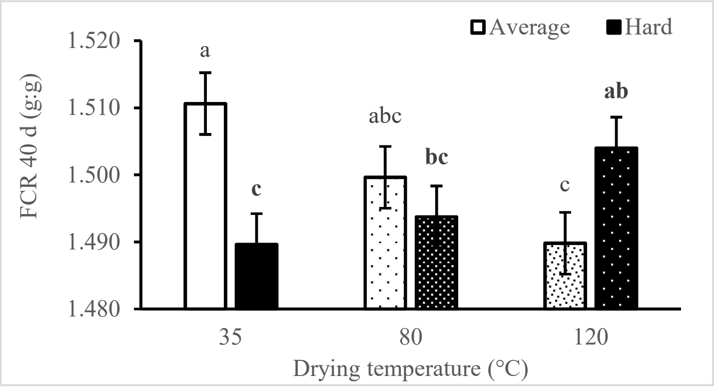
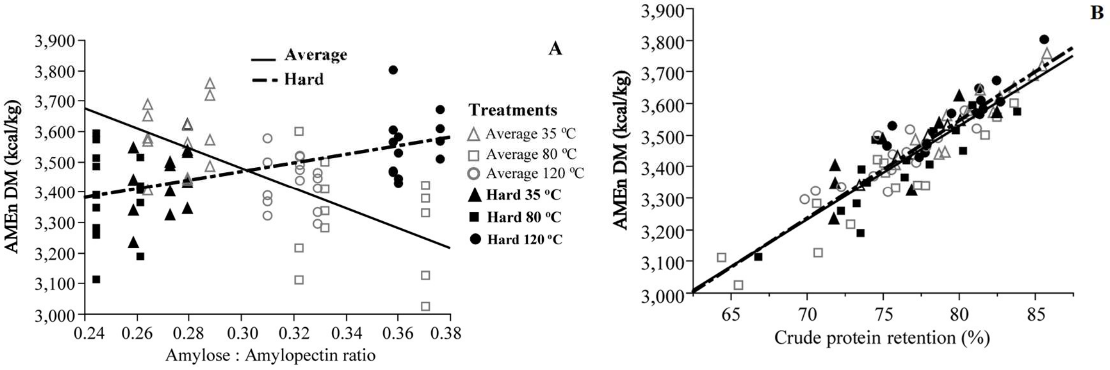


Figure 3. Effect of corn kernel hardness (average and hard) and drying temperature (35, 80, and 120 ºC) on FCR at 40 d. Means not sharing a common superscript (a-c) are significantly different (n=8; P < 0.01) by Tukey's test (Cordova-Noboa *et al.*, 2021b).

The improvements in starch digestibility were well correlated with higher AMEn (Figure 4). For average endosperm hardness, the lower AM: AP ratio is also related to better AMEn, but the most important parameter to explain AMEn variation independently of kernel hardness was the total tract protein digestibility (Figure 4, Panel B). These results confirm the importance of the interactions between starch and protein in total nutrient utilization.



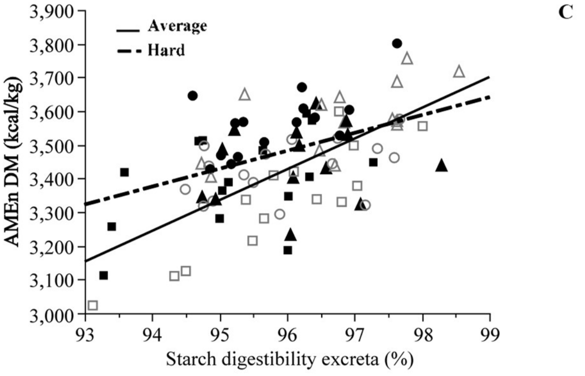


Figure 4. Panel A. Linear effect of amylose content on AMEn at 16 d in corn with average (P < 0.001) and hard kernel (P < 0.001) hardness. For average corn kernel hardness AMEn = 4,437.792 – 3,144.344* amylose:amylopectin ratio AM:AP (R^2 = 0.44). For hard corn kernel AMEn = 3,040.029 + 1,421.562* AM:AP (R^2 = 0.30). Panel B. Linear effect of CP retention assessed in excreta samples on AMEn at 16 d of age in corn with average (P < 0.001) and hard kernel (P<0.001). For average corn kernel hardness AMEn = 1,152.539 + 29.676*CP retention (R^2 = 0.86). For hard corn kernel AMEn = 1,067.541 + 30.942*CP retention (R^2 = 0.79). Panel C. Linear effect of starch digestibility evaluated in excreta samples on AMEn at 16 d of age in corn with average (P < 0.001) and hard kernel (P =0.004). For average corn kernel hardness AMEn = -5,340.215 + 91.327*Starch dig (R^2 = 0.50). For hard corn kernel AMEn = -1,611.428 + 53.057*Starch dig. (R^2 = 0.17). Markers represent the eight means per treatment combination of kernel hardness (average or hard) and drying temperatures (35, 80 or 120 ºC) post-harvest and lines the linear fit by kernel hardness. (Cordova-Noboa *et al.*, 2021b).

Selle and Liu (2019) discussed the relevance of starch and protein digestive dynamics in poultry. Due to thermal treatments, grinding, and pelleting, changes in corn starch structure may alter the digestion rates or starch: protein disappearance ratios. One potential pathway to obtain optimum nutrient utilization of any corn kernel could be to determine the adequate processing levels to obtain the best starch and protein digestion rates under each situation.

Potential parameters for the best corn nutritional value

The best nutritional value and energy utilization estimators could most likely come from an index or indexes that include these biochemical interactions between protein and starch. We have not observed that this specific marker has been established yet. In the meantime, we determined that the best FCR at 40 days came from corn with a lower proportion of amylose within the starch, AM: AP below 0.33 (0.24−0.33), damaged starch higher than 2.69%, vitreousness below 62.7%, and protein solubility higher than 23.5%. The total NSP was weakly correlated ($r = 0.22$) with flock uniformity. We will continue testing whether these values apply to relevant conditions and how these corn traits affect starch and protein digestion dynamics (Selle and Liu, 2019).

Proposal to minimize corn variability

Corn origin and provider should be the first factor to control. Corn genetics is responsible for the great majority of the variability. Consequently, determining the best corn hybrids to use in poultry nutrition could be a logical step. A second important factor in variability is the harvest moisture and drying temperature to use. Negotiating grain drying protocols may contribute to minimizing variability in reactions. NIRS can measure a variety of chemical components of maize to make rapid and better assessments of corn nutritional value. Then, we propose to use NIRS for other physicochemical parameters and not only using it for proximate analyses. Finally, to make effective improvements is necessary to adopt these NIRS values to adjust the matrix in feed formulation (Latham *et al*., 2016; Montanhini-Neto *et al*., 2017). The addition of xylanase, amylase, and protease have been proven to mitigate some of the negative effects caused by processing. The strategic use of these enzymes depending on NSP and starch content and composition could lead to more consistently positive results (Latham *et al*., 2016; Williams *et al*., 2017; Cordova-Noboa *et al*., 2020, 2021b; Melo-Duran *et al*., 2021a, b).

Conclusions

Variability in corn nutrient and NSP content affects corn particle size and distribution post-grinding, pellet durability, growth, feed conversion, flock uniformity, digestibility, AMEn, digesta viscosity, gut microbiota composition, intestinal health, and efficacy of exogenous enzymes. Due to the multiple effects of this variability, actions to control it should be implemented. NIRS is a useful tool to measure important corn physicochemical parameters, NSP, additionally to the nutrient composition frequently used nowadays. Utilization of these new parameters to determine the true nutritional value and AMEn for feed formulation can greatly impact the precision of poultry nutrition. However, designing strategies that truly minimize or control this variability are becoming more important to improve in all aspects of production. The alternatives could include controlling the varieties of corn, the harvest, and kernel drying protocols.

References

AFNOR (Association Française de Normalisation) (2008) Méthode Promatest d'évaluation de la denaturation des proteins Thermosensibles. NF-V03-741. AFNOR, La Plaine Saint-Denis, France.

Córdova-Noboa, H.A., E.O. Oviedo-Rondón, A. Ortiz, Y. Matta, J.S. Hoyos, G.D. Buitrago, J.D. Martinez, J.J. Yanquen, M. Chico, V.E. San Martin, A. Farenhoz, I.C. Ospina-Rojas, and L. Peñuela. 2021a. Effects of corn kernel hardness and grain drying temperature on particle size and pellet durability when grinding using a roller mill or hammermill. Anim. Feed Sci. Technol. 271: 114715 - 114728. doi.org/10.1016/j.anifeedsci.2020.114715 ISSN 0377-8401.

Córdova-Noboa, H.A., E.O. Oviedo-Rondón, A. Ortiz, Y. Matta, S. Hoyos, G.D. Buitrago, J.D. Martinez, J. Yanquen, L. Peñuela, J.O.B. Sorbara, and A.J. Cowieson. 2020. Corn drying temperature, particle size, and amylase supplementation influence growth performance, digestive tract development, and nutrient utilization of broilers. Poult. Sci. 99:5681-5696. doi.org/10.1016/j.psj.2020.07.010.

Córdova-Noboa, H.A., E.O. Oviedo-Rondón, Y. Matta, A. Ortiz, G.D. Buitrago, J.D. Martinez, J. Yanquen, S. Hoyos, A.L. Castellanos, and J.O.B. Sorbara. 2021b. Corn kernel hardness, drying temperature and amylase supplementation affect live performance and nutrient utilization of broilers. Poult. Sci. 100:101395, doi.org/10.1016/j.psj.2021.101395.

Correa, C. E. S., R. D. Shaver, M. N. Pereira, J. G. Lauer, and K. Kohn. 2002. Relationship between corn vitreousness and ruminal *in situ* starch degradability. J. Dairy Sci. 85:3008-3012. doi.org/10.3168/jds.S0022-0302(02)74386-5.

Cowieson, A. J. 2005.Factors that affect the nutritional value of maize for broilers. Anim. Feed Sci. Technol. 119:293–305.

Dei, H. K. 2017. Assessment of maize (*Zea mays*) as feed resource for poultry. In Poultry Science. Manafi, M., ed. Intech Open, London, United Kingdom.

Franciele, C. N. G., C. Eyng, R. V. Nunes, C. de Souza, L. V. Teixeira, R. Pilla, J. S. Suchodolski, and C. Bortoluzzi. 2021. Influence of enzyme supplementation in the diets of broiler chickens formulated with different corn hybrids dried at various temperatures. Animals 11: 643. doi.org/10.3390/ ani11030643.

Gehring, C. K., A. J. Cowieson, M. R. Bedford, and W. A. Dozier. 2013. Identifying variation in the nutritional value of corn based on chemical kernel characteristics. Worlds. Poult. Sci. J. 69:299–312.

Giacobbo, F. C. N., C. Eyng, R. V. Nunes, C. de Souza, L. V. Teixeira, R. Pilla, J. S. Suchodolski, and C. Bortoluzzi. 2021. Different enzymatic associations in diets of broiler chickens formulated with corn dried at various temperatures. Poult. Sci. 100:101013. doi.org/10.1016/j.psj.2021.01.035.

Kaczmarek, S. A., A. J. Cowieson, D. Jozefiak, and A. Rutkowski. 2014. Effect of maize endosperm hardness, drying temperature and microbial enzyme supplementation on the performance of broiler chickens. Anim. Prod. Sci. 54:956–965.

Kljak, K., M. Duvnjak, and D. Grbeša. 2018. Contribution of zein content and starch characteristics to vitreousness of commercial maize hybrids. J. Cereal Sci. 80: 57-62. doi.org/10.1016/j.jcs.2018.01.010.

Latham, R. E., M. P. Williams, C. Flores, H. V. Massey O'Neills, T. W. York, and J. T. Lee. 2016. Impact of variable corn nutrient content, AME prediction, and xylanase inclusion on growth performance. J. Appl. Poult. Res. 25: 338-351. doi.org/10.3382/japr/pfw017.

Melo-Durán, D., Pérez, J.F., González-Ortiz, G., Sala, R., Villagómez-Estrada, S., Bedford, M.R., Graham, H., Solà-Oriol, D. 2020. Influence of particle size and xylanase in cornsoybean pelleted diets on performance, nutrient utilization, microbiota, and short-chain fatty acid production in young broilers. Animals. 10: 1904. doi: 10.3390/ani10101904.

Melo-Durán, D., Perez, J.F., González-Ortiz, G., Villagómez-Estrada, S., Bedford, M.R., Graham, and H., Sola-Oriol, D. 2021a. Growth performance and total tract digestibility in broiler chickens fed different corn hybrids. Poult. Sci. 101218. doi:10.1016/j.psj.2021.101218.

Melo-Durán, D., Pérez, J.F., González-Ortiz, G., Villagómez-Estrada, S., Bedford, M.R., Graham, H., and Sola-Oriol, D. 2021b. Maize nutrient composition and the influence of xylanase addition. J. Cereal Sci. 97: 103155. doi: 10.1016/j.jcs.2020.103155.

Montanhini Neto, R., E. N'Guetta, C. Gady, M. Francesch, and A. Preynat. 2017. Combined effect of using near-infrared spectroscopy for nutritional evaluation of feed ingredients and non-starch polysaccharide carbohydrase complex on performance of broiler chickens. Anim. Sci. J., 88: 1979– 1986. doi: 10.1111/asj.12822.

Nguyen, H. T., M. R. Bedford, S.-B. Wu, and N. K. Morgan. 2021. Soluble non-starch polysaccharide modulates broiler gastrointestinal tract environment. Poult. Sci. 100:101183. doi.org/10.1016/j.psj.2021.101183.

Selle, P. H. and S. Y. Liu. 2018. The relevance of starch and protein digestive dynamics in poultry. J. Appl. Poult. Res. 28:531-545. doi.org/10.3382/japr/pfy026

Williams, M. P., H. V. Masey O'Neill, T. York, and J.T. Lee. 2017. Effects of nutrient variability in corn and xylanase inclusion on broiler performance, nutrient utilisation, and volatile fatty acid profiles. J. Appl. Anim. Nutr., 6:1-10. doi:10.1017/jan.2017.11.

Zuber, T. and M. Rodehutscord. 2017. Variability in amino acid digestibility and metabolizable energy of corn studied in cecectomized laying hens. Poult. Sci. 96:1696–1706. doi.org/10.3382/ps/pew429.