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Investigation of rumen starch and protein degradation kinetics in relation to corn processed by super-conditioned pelleting, extruding and puffing

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Introduction

- Several methods of corn processing have been developed over the last decade to increase starch utilization of corn grain.
- Processing due to the alteration of kernel structure and starch gelatinization is able to increase the accessibility of starch to microbes in the rumen and increases the susceptibility to enzyme activity (Ebrahimi, 2020).
- Conventional-conditioner is a part of pellet production line that the ground corn grain passes through while heated at 75−85 °C for a maximum of 15–20 seconds (Lewis et al., 2015). This processing increases the content of gelatinized starch from 5.9 to 16.9 % at a conditioner temperature of 75 °C (Abdollahi et al., 2013).
- Super-conditioning is a new conditioning technology in corn processing that can provide the benefits such as more starch gelatinization and digestibility through the long-lasting treatment capacity, temperature controlling and perfect mixing of starch and gluten molecules in grain particles (Puntigam et al., 2016; Attar et al., 2017; Rahimi et al, 2020).
- The effective rumen degradability of starch and CP were greater in super-conditioning pelleted corn in comparison with steam-flaked, dry-rolled and grounded corn (Rahimi et al, 2020). However, it is not clear yet whether super-conditioning increases starch gelatinization and digestibility of corn grain in comparison with stronger heat treatments.

Objectives

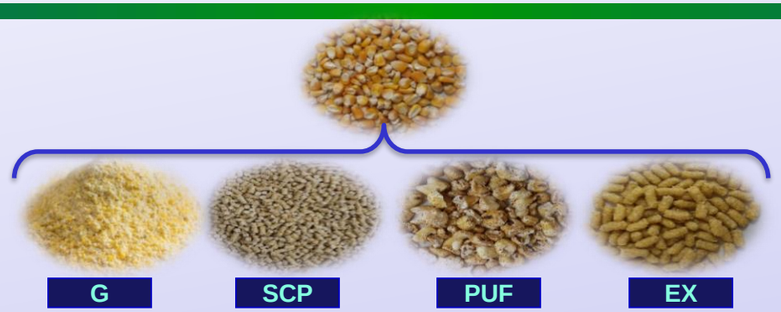
The aim of this study was to investigate the rumen starch and protein degradation kinetics in relation to corn processed by super-conditioned pelleting, extruding and puffing processes.

Materials and methods

- An Iranian corn variety (single crass 702) was processed by 4 processing methods.
- Applied processing methods were: 1) grinding (**G**, 2mm), 2) super-conditioned pelleting (**SCP**; moisture 20%, retention time 6 min and conditioning temperature 95ºC), 3) puffing (**PUF**; puffing temperature 200ºC, hot air velocity 25 m/s, feed rate 100 g/m) and 4) extruding (**EX**; moisture 20%, temperature of melting zone 75ºC and die zone 125ºC and time 150s).
- Three lactating Holstein cows (LW 650 ± 15 kg) fitted with a ruminal cannula were used.
- Samples were incubated into the rumen for 2, 4, 8, 12, 24, and 48 h. Six measurements (two repetitions for three cows) were performed for each incubation time. Protein and starch of un-incubated and incubated residues were determined using Kjeldahl procedure (AOAC, 2012) and the enzymatic method (megazyme kit, example c, 9/2018), respectively.
- Data were incorporated in the exponential equation of Ørskov and McDonald (1979). In situ effective degradability (ED) was calculated (Ørskov and McDonald, 1979), based on the fractional passage rate (Kp) 0.08 % h−1.

Statistical analyses

Data were analyzed by GLM procedure of SAS (P<0.05) using a completely randomized design with 6 replications for every treatment by the model; Y = μ +Txi+εij, were Y is the variable, Txi is the effect due to the treatment, and εij is the experimental error.



Results

- Rapidly soluble fraction (a) and fractional rate constant (c) of dry matter (DM) were higher (P<0.01) in PUF and EX corns than SCP corn. The lowest a and c fraction of DM was observed in G corn.
- The lowest (P<0.05) slowly degradable fraction (b) of DM was found in SCP and the highest (P<0.05) slowly degradable fraction (b) of DM was found in G corn.
- Processing of corn with EX, PUF and SCP methods was significantly increased (P<0.01) a fraction of starch and protein.
- The rate of degradability (c) of starch, DM and protein in EX and PUF were similar and higher (P<0.01) than SCP and G, but c for starch in EX was greater (P<0.01) than PUF and fallowed by SCP and G corns.
- The highest (P<0.01) effective rumen degradability of DM (ERDM), starch (ERDS) and protein (ERDP) were observed in the EX, followed by PUF, SCP and G corns.

Table 1. Rumen DM, starch and protein degradation kinetics

Kinetic parameters [1]	Treatments [2] G	SCP	PUF	EX	SEM	P-Value
DM [3]						
a, %	6.13 [c]	23.91 [b]	26.73 [a]	28.60 [a]	2.05	0.005
b, %	99.04 [a]	70.28 [d]	72.85 [c]	78.05 [b]	2.44	0.003
c, h^{-}	0.42 [c]	0.57 [b]	0.74 [a]	0.79 [a]	0.75	0.004
Starch						
a, %	4.87 [b]	33.68 [a]	34.35 [a]	35.74 [a]	2.85	0.008
b, %	97.53 [a]	68.84 [b]	67.08 [c]	64.61 [d]	3.05	0.004
c, h^{-}	0.57 [d]	0.78 [c]	0.97 [b]	1.47 [a]	0.07	0.009
Protein						
a, %	11.03 [b]	18.07 [a]	17.06 [a]	18.68 [a]	0.59	0.007
b, %	64.08 [b]	64.71 [b]	62.38 [c]	67.21 [a]	1.61	0.003
c, h^{-}	0.39 [c]	0.58 [b]	0.77 [a]	0.75 [a]	0.04	0.006

[1](a): rapidly soluble fraction; (b): slowly degradable fraction; (c): fractional rate constant at which (b) is degraded.
[2] G: Grinding, SCP: Super-conditioned pelleting, PUF: Puffing, EX: Extruding.
[3] DM: dry matter

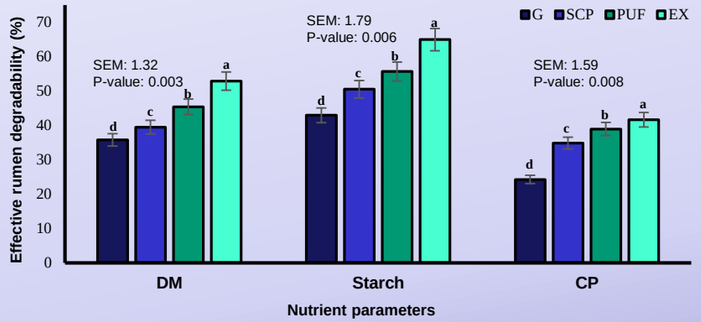


Figure 1: Effective rumen degradability of DM, starch and protein of corn processed by G: Grinding, SCP: Super-conditioned pelleting, PUF: Puffing and EX: Extruding. Fractional passage rate (Kp) 0.08 % h-1.

Discussion

- Finding of this study was in agreement to Rahimi et al (2020) that revealed a fraction and degradability rate of starch and protein in super-conditioning pelleted and steam-flaked corns were increased in comparison with dry rolled and grounded corns.
- The extrusion of corn generally was more intense, resulting in a greater degree of chemical and structural transformations, including protein denaturation and starch gelatinization, greatly enhancing starch enzymatic reactivity (Buenabad et al, 2019). Christian Alvadaro et al (2009) a higher digestibility of NFC observed with the ration supplemented with extruded corn (82.63%) in comparison with steam rolled (81.18%) and grounded corns (77.42%).
- The crystalline structure disruption, polysaccharides dissolution, and the ruptured granules diffusion are the results of combining moisture, heat, and pressure, which lead to the gelatinization of starch granules (swelling of granules after absorbing water), thereby enhancing the amount of starch fermented in the rumen and starch intestinal digestibility escaping the rumen degradation (Safaei and Yang, 2017)
- Results of this study offered new insights into the rumen kinetic dynamics and the location of starch digestion on the corn grain processed by SCP method in comparison with the corn grain subjected to stronger processing methods like PUF and Ex methods.

Conclusion

It seems that although the SCP method is not more intense than PUF and EX methods, reduction of particle size, homogenous mixing, and longtime exposure of direct steam injection (6 min with 95 ºC) in this method could be reasons for higher starch gelatinization and starch degradability rate.

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