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Effect of conventional and extrusion pelleting on *in situ* ruminal degradability of starch, protein, and fibre in cattle

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ABSTRACT

Rumen degradability kinetics was investigated for pelleted compound concentrates differing in physical functional properties of pellets. Six compound concentrate meals were produced containing either 100% wheat, 100% maize, 50% wheat+50% soybean meal (SBM; as is basis), 50% maize+50% SBM, 50% wheat+50% sugar beet pulp (SBP), or 50% maize+50% SBP. Meals were pelleted by either conventional pelleting, or by cooking extrusion using two distinct settings giving pellets with either high density (HD) or low density (LD). Ruminal degradation of starch, crude protein (CP) and NDF, and intestinal digestibility of CP were evaluated using *in situ* methods in cattle. Overall, processing (pelleting, extruding HD, or extruding LD) increased effective starch degradability (ESD) of pure maize and maize mixtures. The ESD increased with intensity of processing (Extruding LD > Extruding HD > Pelleting > Meal). In contradiction, ESD for pure wheat and wheat mixtures was reduced, though differences were minor. Conventional pelleting reduced the effective protein degradability (EPD) for pure wheat, but extrusion did not further affect the EPD. In contrast, the most intense processing with extrusion LD increased EPD for pure maize. Processing reduced EPD in both cereal+SBM mixtures, and further, the most intense processing with extruding LD led to the lowest EPD in cereal+SBM mixtures. In contrast, extruding increased EPD in both cereal+SBP mixtures as compared with meal and pelleting, but extruding with steam addition did not further increase the EPD. Compared to meal and pelleting, extruding without steam addition increased the effective NDF degradability for maize+SBP. The observed responses in EPD were not associated with decreases in CP disappearances from mobile bags. In conclusion, pelleting and extrusion affected ruminal degradability of starch, protein, and NDF differently depending on both type of cereal and composition of the concentrate mixture.

1. Introduction

Concentrate feedstuffs are often industrially processed to compound mixtures and subsequently pelletized to ease on-farm allocation. Pelletizing of compound concentrates for cattle has traditionally been conducted using conventional pellet presses where rollers press the compound meal through a steel dye. In the fish feed industry, however, cooking extrusion is used to obtain compound feed pellets with high nutrient availability combined with specific physical functional properties of pellets suitable for allocation in water, e.g. high water stability and low sinking velocity (Kraugerud et al. 2011; Sørensen, 2012). In comparison, pellets produced by conventional pelleting have low water stability and high sinking velocity. Separate allocation of pelletized concentrate as compared with TMR has been observed to decrease rumen pH (Maekawa et al., 2002) and to reduce feed intake and milk production (Ingvartsen et al., 2001). Hence, it could be speculated that the compromised rumen environment is caused by the within rumen behaviour of feed pellets produced by conventional pelleting. Therefore, there may be beneficial effects on rumen environment and performance of feeding compound concentrates with physical functional properties that potentially allow different within rumen behaviour.

Processing of concentrates can modify the rate and extent of starch and protein digestion in the rumen and is an important tool to change the partitioning of starch and protein digestion between rumen and intestines (Prestløkken, 1999; Tothi et al., 2003). Physical processing will break the physical barrier of hull and pericarp, which on one hand allow access of rumen microorganisms and digestive enzymes to the nutrient rich endosperm, and on the other hand, physical processing with high temperature (pelleting,

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extruding, and expanding) can result in significant amounts of starch or protein escaping the rumen and hence entering the small intestine (Dakowski et al., 1996; Tothi et al., 2003). Cooking extrusion is a high-temperature (80–200 °C), short time process which involves physical and chemical changes in feedstuffs, especially in the starch and protein structures (Camire et al., 1990; Sørensen, 2012). However, coherent investigations of several processing methods on rumen degradation kinetics of several nutrients are scarce.

Hence, the study aimed to investigate rumen nutrient degradability kinetics in compound concentrates with different physical functional properties. We hypothesised that as compared to meal 1) conventional pelleting increases starch and decreases protein rumen degradability, 2) extruding affects degradability more than pelleting, and 3) steam addition during extruding further increases the effect.

2. Materials and methods

2.1. Experimental concentrates and animals

Six compound concentrate meals were produced containing either 100% wheat (as is basis, Table 1), 100% maize, 50% wheat + 50% soybean meal (SBM), 50% maize + 50% SBM, 50% wheat + 50% sugar beet pulp (SBP), or 50% maize + 50% SBP. Meals were produced using a hammer mill (P50SP, President, Herning, Denmark) with a 2 mm screen. Each concentrate meal was subdivided into three portions for pelleting (3 mm) by either conventional pelleting with steam to 81 °C (M-6K with 3×50 mm^2 dye, Jesma-Matador, Esbjerg, Denmark) or by cooking extrusion (BC-45 twin screw with 2.4 or 2.6 mm circular dye, Clextral, Firmini, France) using two distinct settings giving pellets of either high density (HD) or low density (LD). Low density pellets were obtained by steam addition to 115 °C resulting in concentrate meal expansion when extruded through the dye. High density pellets were obtained by limiting the extent of concentrate meal expansion by water cooling of the extruder barrel to keep temperature on maximum 90 °C.

The animal experiment complied with the guidelines of the Danish Ministry of Justice with respect to animal experimentation and care of animals. All cows were housed in tie stalls with rubber mats, and had free access to water. Three dry Danish Holstein cows fitted with a rumen cannula (No. 1C; Bar Diamond Inc., Parma, ID, USA) were used for determination of ruminal degradation. The three dry cows were fed twice daily (8.30 and 17.30 h) with a standard ration in accordance to the NorFor standard (Åkerlind et al., 2011). The diet consisted of 4 kg/d artificially dried grass hay, 2.8 kg/d concentrate (containing in g/kg: 400 barley, 400 oats, 100 SBM, 30 rapeseed meal, 30 beet molasses, and 40 mineral–vitamin premix), 2 kg/d spring barley straw, and 150 g/wk vitamin mix. Ration chemical composition (g/kg DM) was 139 crude protein (CP), 465 NDF, and 137 starch. Three lactating Danish Holstein cows (average milk yield of 25 kg/d) fitted with duodenal and ileal cannulas were used for the determination of CP disappearance in the total digestive tract using mobile bags. The diet was fed ad libitum as a total mixed ration and consisted of (g/kg DM) 305 maize silage, 201 grass-clover silage, 8 barley straw, 220 rolled barley, 70 SBP, 148 rapeseed cake, 36 SBM, and 10 mineral–vitamin premix. Ration chemical composition was (g/kg DM): 154 CP, 310 NDF, and 261 starch.

2.2. In situ procedures

The *in situ* procedure for measuring rumen degradation and the mobile bag procedure for measuring intestinal digestibility were as described by Madsen et al. (1995) and performed as modified to the NorFor system (Åkerlind et al., 2011). Approximately 2 g of each ground concentrate sample was weighed into 38 μm Dacron bags with 11×8.5 cm^2 dimensions (Saatifil PES 38/31, Saatitech S.

Table 1
Chemical composition and bulk density of compound concentrates as meal, conventional pellets, and as pellets produced by extruding yielding either high density (HD) or low density (LD) pellets.

Concentrate mixture	Processing	DM, g/kg	Composition, g/kg DM						pdNDF[a], g/kg NDF	EFOS[b], g/kg OM	Density, g/L
			Ash	CP	Starch	NDF	iNDF[c]	Carbon			
100% wheat	Meal	889	16	126	667	100	16	448	840	978	712
	Pelleting	883	17	125	673	93	14	448	849	977	760
	Extruding HD	915	17	130	681	98	18	451	816	981	683
	Extruding LD	954	17	129	677	97	18	450	814	974	458
100% maize	Meal	895	15	90	713	93	5.9	451	937	984	639
	Pelleting	901	16	90	726	75	5.5	451	927	987	797
	Extruding HD	921	16	95	728	79	5.1	456	935	977	633
	Extruding LD	947	16	92	715	78	4.8	455	938	979	428
50% wheat + 50% soybean meal	Meal	896	47	329	342	99	10	454	899	990	736
	Pelleting	884	47	318	365	85	8.7	451	898	993	756
	Extruding HD	924	48	329	344	95	10	455	895	992	701
	Extruding LD	949	48	332	337	97	11	457	887	990	516
50% maize + 50% soybean meal	Meal	892	47	307	362	86	5.8	454	933	992	716
	Pelleting	884	47	312	363	80	4.9	456	939	995	763
	Extruding HD	929	47	308	354	88	4.9	457	944	992	691
	Extruding LD	949	47	313	340	86	5.0	457	942	990	505
50% wheat + 50% sugar beet pulp	Meal	901	44	107	361	258	27	441	895	980	719
	Pelleting	878	42	108	349	262	25	441	905	973	800
	Extruding HD	929	43	111	337	254	26	441	898	978	565
	Extruding LD	938	43	113	327	262	26	441	901	980	467
50% maize + 50% sugar beet pulp	Meal	902	43	93	348	258	21	442	919	969	712
	Pelleting	886	39	99	362	256	20	444	922	973	761
	Extruding HD	958	41	97	359	257	20	444	922	973	501
	Extruding LD	971	42	97	364	257	21	441	918	972	452

[a] Potentially degradable NDF.
[b] *In vitro* enzymatic organic matter digestibility.
[c] Indigestible NDF.