Effect of whole cereal grains contained in the ration on calf performance and selected morphometric parameters of the rumen and small intestine

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ABSTRACT: The aim of this study was to determine the effect of whole maize and oat grains contained in starter concentrates on the performance of calves (during the first 90 days of their life) and selected morphometric parameters of the rumen and small intestine. The study was conducted on two groups of Holstein-Friesian calves (each of 3 males and 9 females) during the first 90 days of their life. After colostrum feeding all calves were given a milk replacer. Group 1 (control) received a concentrate (containing ground cereal grains) and meadow hay. Until 4 weeks of age group 2 (experimental) received a concentrate mixed with 25% of whole maize grains, followed by a concentrate mixed with 25% of whole maize grains and 25% of whole oat grains. The rations were supplemented with hay in the last two weeks of the experiment. Feeding the concentrates based on ground cereal components to calves (until 30 days of age) enabled to increase both feed intake and daily body weight gains. The addition of whole maize and oat grains to diets for the calves of experimental group significantly increased their mean daily gains throughout the experimental period, compared to the calves of control group (906 g vs. 769 g). At 90 days of age, the bulls of experimental group were characterised by thinner ($P < 0.01$) ruminal epithelium, including a thinner cornified layer (17.50 vs. 33.39 μm). Those calves also had thicker duodenal epithelium ($P < 0.01$) and thicker jejunal mucosa ($P < 0.05$). Moreover, the calves of experimental group had regular and tall intestinal villi, which were irregular in the calves of control group and varied in length and shape. The obtained results indicate that it is recommended to supplement whole maize and oat grains to diets for calves, starting from the second month of life.

Keywords: whole cereal grains; calf performance; morphometric parameters; rumen; small intestine

In modern cattle production systems diet optimization, in particular at the early stage of calves' life, is of primary importance for their further growth and development. This is related to the specific structure and functions of the digestive tract of calves (Kertz et al., 1998). Xu et al. (1992) demonstrated that during the first days of animals' life, stomach weight increases by 25% and hydrochloric acid secretion increases twice. At the same time, the weight, length and width of the small intestine increase by 70%, 24% and 15%, respectively, while the depth of intestinal crypts and the length of intestinal villi increase by 24% and 33%, respectively. Considerable changes are also observed over this period in the structure of intestinal mucosa, under the influence of various nutritional factors (Zhang et al., 1997; Zitnan et al., 2003).

Calf performance is affected not only by the properties of liquid milk replacers, but also by the texture of solid feed particles and the feeding period

(Longenbach and Heinrichs, 1998; Niwińska and Strzetelski, 2005). The rate of changes as well as the development and stabilisation of the physiological functions of the digestive tract of calves, and dry matter intake are related to the physical structure of feed (Greenwood et al., 1997; Villalba and Provenza, 1999; Baldwin, 2000). Feeding starter diets with cereal grains to very young calves enables to reduce the consumption of milk replacers and allows early weaning, which diminishes feeding costs and exerts a beneficial influence on the growth and development of animals (Franklin et al., 2003).Volatile fatty acids (in particular propionic acid and butyric acid) produced during nutrient fermentation are essential for inducing physiological changes in the functions of the stomach in calves, evolving from those typical of monogastric animals (at birth) to those characteristic of adult ruminants (Warner, 1991; Lesmeister and Heinrichs, 2004). The stimulation of rumen development by volatile fatty acids is indicative of a correlation between anatomical changes in the rumen (including the growth of ruminal papillae) and microflora growth (Baldwin, 1998; Beharka et al., 1998; Lane et al., 2000). Previous studies (Nocek et al., 1984) showed that the texture and size of feed particles affect the growth of ruminal papillae. Greenwood et al. (1997) reported that finely ground concentrate, compared to coarsely ground feed, contributes to the keratinization of ruminal epithelial cells and reduces the absorption of volatile fatty acids. Enhanced keratinization of the mucosa increases the proportion of branched and irregular ruminal papillae, which suggests a possibility of changes in the metabolic activity of ruminal walls. In addition, a larger size of feed particles and feeding starter diets differing in physical form to calves at the early stage of their life have a positive effect on the anatomical development of the rumen, and on production results (Warner, 1991; Greenwood et al., 1997; Franklin et al., 2003; Lesmeister and Heinrichs, 2004; Bach et al., 2007; Węglarzy and Bilik, 2008).

A fast growth rate of the rumen and small intestine is observed in calves fed concentrates with a high cereal starch content (Zitnan et al., 1998). Whole cereal grains (in particular maize and oat ones) contained in a starter diet constitute an important structural component of the ration which stimulates the growth and motor activity of the forestomach. Lesmeister and Heinrichs (2004) reported higher feed consumption and better production results in calves fed a starter diet with 33% supplement of whole maize, in comparison with animals fed a diet containing thermally processed maize.

According to Górka and Kowalski (2008), whole oat grain is a key component of diets for calves. Oat grain is a rich source of fibre which plays a significant role in the normal function of the gastrointestinal tract in calves. However, oat starch is rapidly fermented in the rumen, compared with other cereal species fed to calves. As a result of metabolic changes, oat starch may excessively reduce the pH of ruminal fluid, thus decreasing the intake of solid feed (Khan et al., 2007). Górka and Kowalski (2008) demonstrated that the concentration of whole oat grain in starter diets for calves should not be higher than 20–25%. According to these authors, feeding whole cereal grains to calves has a beneficial influence on the development of the muscular layer of the rumen, and prevents the keratinization of the ruminal mucosa due to mechanical abrasion of the epithelium. This suggests that hay can successfully be replaced with whole cereal grain as a structural component in diets for calves. Węglarzy and Bilik (2008) reported that both the growth rate of heifer calves and feed conversion were positively affected by feeding smaller amounts of whole milk (185 kg per head, from 6 weeks of age) and whole maize and oat grains (from 6 to 90 days of age), as compared with a traditional diet composed of ground cereals and hay. However, it should be stressed that the effectiveness of the inclusion of whole cereal grain in starter diets for calves has not been widely documented to date.

Therefore, the aim of the present study was to determine the effect of whole cereal grain (maize and oat) contained in starter diets on calf performance and selected morphometric parameters of the rumen and small intestine.

MATERIAL AND METHODS

Animals and experimental design

An experiment was performed on 24 Holstein-Friesian (100%) calves (from birth to 90 days of age), placed in single cages on straw litter. The experiment was approved by the local Animal Ethics Committee at the University of Warmia and Mazury in Olsztyn.

On the first 5 days of their life, the calves received colostrum in the amount of 4–6 kg/head/day, divided into 3 doses. From day 6 to 30, the calves were given 6 litres of liquid feed, composed of 130 g of milk replacer per litre of water. From day 31 to 60, the animals were fed milk replacer in the amount of 3 litres/head/day (1 litre of liquid feed contained 110 g of milk replacer 2). Milk replacer contained skim milk, whey, buttermilk powder and processed soybean protein, fat, vitamins and minerals (there is no information on the percentage content of particular components on the label). Milk replacer was prepared as recommended by the manufacturer. Calves, selected for the experiment during a three-week period, were divided into two groups (each of 12 animals – 3 males and 9 females) identical in terms of birth weight. From 8 to 90 days of age group 1 (control) received concentrate 1 (composition, in %: wheat bran – 15, soybean meal – 18, ground barley – 33, ground triticale – 30, mineral mixture: limestone – 1, dicalcium phosphate – 1, mineral-vitamin premix – 2) and meadow hay. At 2 and 3 weeks of age group 2 (experimental) received a concentrate (composition, in %: wheat bran – 20, soybean meal – 30, ground barley – 30, ground triticale – 16, mineral mixture – 4, as in concentrate 1) mixed with whole maize grains at a weight ratio of 3:1 (concentrate 2). From 4 weeks to the end of the experimental period calves were fed a concentrate (composition, in %: wheat bran – 28, soybean meal – 44, ground barley – 12, ground triticale – 10, mineral mixture: limestone – 1.5, dicalcium phosphate – 1.5, mineral-vitamin premix – 3) mixed with whole maize grains and whole oat grains at a weight ratio of 2:1:1 (concentrate 3). The mineral-vitamin premix contained, in 1 kg (g): Ca – 183, P – 72, Mg – 43, Na – 80, Mn – 2.0, Zn – 3.75, Fe – 2.9, Cu – 0.375, Co – 0.012, J – 0.050, Se – 0.0125, biotin – 0.0006, vitamin B_{12} – 0.0006, vitamin E – 1.5, vitamin D_3 – 200 000 IU and vitamin A – 1 000 000 IU. The composition of diets fed to calves during the experiment is presented in Table 1. In the last two weeks of the experiment, diets were supplemented with meadow hay (when the concentrate intake was ca. 2 kg). Solid feed (concentrate, meadow hay) was offered *ad libitum* to all calves. Feed intake, daily weight gains and feed consumption per kg weight gain were monitored over the experimental period.

The body weights of calves were determined at birth as well as on day 30, 60 and 90.

Chemical analysis of feed

The nutrient content of solid feed was determined as recommended by AOAC (1995). The fractions of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according

Table 1. Composition of the concentrate (%)

Ingredient	Concentrate		
	1	2	3
Barley (ground)	33	22	5
Triticale (ground)	30	12	5
Wheat bran	15	15	14
Soybean meal	18	22	22
Whole maize grains	–	25	25
Whole oat grains	–	–	25
Limestone	1	1	1
Dicalcium phosphate	1	1	1
Mineral-vitamin premix*	2	2	2

*the mineral-vitamin premix contained, in 1 kg (g): Ca 183, P 72, Mg 43, Na 80, Mn 2.0, Zn 3.75, Fe 2.9, Cu 0.375, Co 0.012, J 0.050, Se 0.0125, biotin 0.0006, vitamin B_{12} 0.0006, vitamin E 1.5, vitamin D_3 200 000 IU and vitamin A 1 000 000 IU

Table 2. Chemical composition and nutritive value of feed

Item	Feed					
	concentrate			meadow hay	milk replacer	
	1	2	3		1*	2**
Dry matter (g)	884.80	882.10	872.00	870.60	946.20	953.30
In 1 kg DM						
Crude protein (g)	213.40	211.50	210.50	79.80	232.60	230.80
Ether extract (g)	20.40	27.20	26.00	15.30	158.60	96.20
Crude fibre (g)	62.70	54.00	70.50	340.00	7.10	7.20
NDF (%)	23.43	24.89	25.16	47.60	–	–
ADF (%)	8.12	7.77	8.19	31.20	–	–
Ash (g)	65.20	59.20	48.50	63.70	79.50	78.90
UFL	1.15	1.16	1.14	0.73	1.62	1.57
PDIN1 (g)	139.00	146.00	140.00	72.50	221.00	219.30
PDIE1 (g)	121.00	125.00	122.00	81.90	–	–
Ca (g)	10.18	10.46	10.30	5.96	7.10	7.15
P (g)	6.89	6.78	5.59	2.41	6.34	6.30
Mg (g)	1.41	1.36	1.56	1.22	2.11	2.10
Na (g)	0.53	0.51	0.56	0.24	7.61	7.55
Fe (mg)	24.61	25.78	29.24	189.50	126.80	125.90

1 PDI for milk replacer corresponds to digested crude protein
*until 30 days of age
**from day 31 to 60

to the procedure of Van Soest et al. (1991), using Fibertec 2010 (Foss Tecator, Sweden). The mineral composition of feed was determined by atomic absorption spectrophotometry (ASA), following the feed sample ashing in a muffle furnace. The energy value and protein content of solid feed were estimated based on the results of chemical analyses, using Winwar software ver. 1.3 (Kowalski and Kański, 1993). Rumen protein degradability ("deg") and intestinal digestibility of rumen non-degradable protein ("dsi") for meadow hay and concentrate components were adopted based on INRA feed tables (1988). As regards milk replacer, it was assumed that "deg" = 0 (due to the function of the reticular groove) and "dsi" = 0.95 (INRA, 1988), which was equivalent to the digestibility of crude protein. The concentrate composition was determined using the INRA-tion 3.22 software package.

Examinations of the gastrointestinal tract of calves

At 90 days of age, three young bulls of each group were sacrificed and segments of their digestive tracts (rumen, small intestine) were taken for analysis. The gastrointestinal tracts of calves were analyzed at the Department of Pathology and Pharmacology (Pathological Anatomy Unit), Faculty of Veterinary Medicine, University of Warmia and Mazury in Olsztyn. The weight of empty rumen (without the contents) and small intestine as well as the circumference of particular segments of the small intestine (duodenum, jejunum and ileum) were determined by cutting the muscular coat of the intestine along fibres.

Samples of the digestive tract of calves were collected for a histopathological examination. Samples were fixed in buffered 10% formalin, embedded in paraffin blocks, and the obtained microtome sections were stained with haematoxylin and eosin (HE) and periodic acid Schiff (PAS), according to McManus and Mowry (1960). Microscopic examinations of the rumen and small intestine were conducted to determine the thickness of: ruminal epithelium, cornified layer of ruminal epithelium, duodenal epithelium, jejunal epithelium, duodenal mucosa and jejunal mucosa, using a Motic light microscope, a Panasonic GP-KRZZE digital camera and Lucia M/Cornet Version 3.52a software (Precoptic Co.). The epithelium thickness was measured at 20× magnification, which corresponds to 0.405844 micrometer per pixel. The thickness of ruminal epithelium was measured from the basement membrane to the surface, and the thickness of the keratinized layer encompassed the layer of necrobiotic keratinocytes without nuclei. Samples for a histological examination were taken from identical sites of the dorsal and cranial sac of calf rumen. According to Lesmaister et al. (2004), samples should be taken from the cranial sacs of the dorsal and ventral rumen to sufficiently represent papillae growth and development. The thickness of intestinal mucosa was measured from the basement membrane of the crypt bottom to the tip of the villus, and the thickness of intestinal epithelium was measured from the basement membrane to the bottom of the striated border in the central part of the villus. Mitotic index (the ratio between the number of cells in mitosis and 100 crypt cells) was also determined. Three slides were obtained randomly from each bull calf (3 head per group). Forty measurements were performed in the central part of each slide (10 measurements in 4 successive vision fields). Statistical calculations were performed for each of the analysed parameters based on n = 120 measurements.

Table 3. Body weight, daily gains and feed conversion per kg of weight gain of calves

Item	Groups		SEM	*P*
	control	experimental		
Body weight (kg[1])				
Newborn	38.0^{A}	37.5^{A}	2.02	0.832
30 days	61.0^{B}	56.7^{B}	2.74	0.067
60 days	82.9^{C}	85.8^{C}	3.04	0.076
90 days	107.2^{D}	117.9 ^{D**}	3.89	0.001
Daily weight gain (g) in (days)				
1–30	765.7^{A}	641.0^{A}	36.32	0.012
31–60	756.6^{A}	971.5^{B**}	39.14	0.001
61–90	821.7^{A}	1 070.1^{C**}	46.26	0.001
1–90	769.0^{A}	906.2^{B**}	44.36	0.001
Conversion per kg of weight gain (whole experimental period)				
Concentrate (kg)	1.40	1.55	0.08	0.543
Dry matter (kg)	2.31*	1.72	0.09	0.024
Crude protein (g)	461*	390	20.32	0.010
PDI (g)	319*	269	10.81	0.013
UFL	2.85*	2.28	0.10	0.037

[1]body weight of males and females together

^{A,B,C,D}differences between the periods of study (P < 0.01)

*differences between the control group and the experimental group (P < 0.05)

**differences between the control group and the experimental group (P < 0.01)

Statistical analysis

The results were verified statistically by an analysis of variance (Anova) in a one-factor orthogonal design, using STATISTICA 7.0 software.

RESULTS AND DISCUSSION

The chemical composition and nutritive value of milk replacer (1, 2) and solid feed offered to calves are presented in Table 2. The concentrates (1, 2, 3) fed to calves (groups 1 and 2) had comparable concentrations of energy (UFL) and total protein, PDIE and PDIN, which indicates that they were isoenergetic and isoproteinaceous.

The birth weights of all calves were similar, reaching 38 kg in the control group and 37.5 kg in the experimental group (Table 3). It was found that feeding the diets containing whole maize grains to calves during the first weeks of their life decreased their growth rate, compared to calves of the control group (641 g vs. 765.7 g/day, non-significant differences). At the next stages of the study the growth rate of calves of the experimental group increased significantly. Over the entire experimental period, the average daily gains of calves fed whole cereal grains (maize and oat) reached 906 g, and were by 17.8% higher than in the control group (769 g).

During the period when calves received the milk replacer (until 30 days of age), the intake of concentrate depended on its physical form, and it reached on average 0.34 kg per day in the control group and 0.28 kg per day in calves fed a diet with whole cereal grain. Over the entire experimental period the consumption of concentrate per kg weight gain was higher in the experimental group (1.55 vs. 1.40 kg). The calves of this group also showed better feed utilisation, as reflected in significantly ($P \leq 0.05$) lower nutrient utilization per kg weight gain (Table 3).

The results of the present study show that the physical form of concentrated feed may affect calf performance. It was found that during the period of the increased intake of liquid feed (colostrum, milk replacer), i.e. for the first 30 days, the calves fed a diet containing ground cereal grain were characterised by a faster growth rate. It probably resulted from higher (by more than 17%) feed intake by the calves of control group, compared to the calves receiving 50% whole cereal (maize and oat) grain in the diet. It seems that at the early stage of rumen development ground components of the ration may be better utilised by calves. This suggestion was confirmed by, among others, Beharka et al. (1998), who reported that the feed particle size may considerably affect not only feed intake but also the function of the rumen and nutrient digestibility at the early stage of rearing. According to Strzetelski et al. (2001b), a concentrate containing ground cereal components offered to calves during the period of the increased intake of liquid feed may positively affect production results. In our study, during the period of the increased intake of liquid feed (day 7 to 56), higher weight gains were observed in the calves of control group fed ground cereal components, compared to the calves of experimental group receiving a pelleted diet (700 g/day vs. 657 g per day). The average daily gains of calves fed whole maize and oat grains were relatively high. Coverdale et al. (2004) fed ground and unground maize and oat grains to calves during the pre-weaning period, and noted daily gains of approximately 540 g/day. At the next stage of the present study (day 31 to 90), significantly ($P < 0.01$) higher daily gains were observed in the group of calves fed the concentrate containing whole maize and oat grains. The effect of the physical form of feed on calf performance and feed conversion was also described by other authors (Bach et al., 2007; Strzetelski et al., 2001a). Warner et al. (1973) demonstrated that calves fed starter diets containing both coarsely or finely ground ingredients were characterized by higher daily gains and feed intake, in comparison with calves fed identical diets in pelleted form. More recent studies (Franklin et al., 2003) indicate that starter diets for calves containing coarsely ground components enabled to achieve better production results than pelleted or friable feed. Lesmeister and Heinrichs (2004) observed higher daily gains (during the first 6 weeks of age) in calves receiving whole maize (WM) in a starter diet, compared to those fed steam-flaked maize (SFM) (469 g vs. 433 g/day). At the same time, the consumption of both feed and dry matter (milk replacer and starter diet) was higher ($P < 0.05$) in calves fed WM than in those fed SFM. The above authors recorded the highest daily gains (474 g) and feed intake (589 g) in calves receiving dry-rolled maize (DRM). Węglarzy and Bilik (2008) found that the concentrate with whole maize and oat grains (from 6 to 90 days of age) had a more beneficial effect on feed conversion and the growth rate of heifer calves, compared with conventional feeding (804 vs. 740 g/day). However, other authors (Coverdale et al., 2004) observed no

Table 4. Some morphometric parameters of the rumen and small intestine of calves

Item	Groups		SEM	P
	control	experimental		
Average weight (kg)				
Rumen	1.30	1.33	0.09	0.872
Small intestine	2.03	2.77*	0.21	0.050
Circumference (cm)				
Duodenum	5.20	5.00	0.10	0.374
Jejunum	5.63	4.53	0.33	0.086
Ileum	7.10	5.50*	0.41	0.020
Thickness (μm[1])				
Rumen				
– epithelium	127.12**	97.24	3.18	0.001
– keratinized layer	33.39**	17.50	0.55	0.001
Duodenum				
– mucosa	630.18	620.95	7.78	0.553
– epithelium	22.50	23.89**	0.17	0.001
Jejunum				
– mucosa	506.63	541.71*	8.18	0.032
– epithelium	22.5**	19.83	0.25	0.001

*differences between the control group and the experimental group ($P < 0.05$)
**differences between the control group and the experimental group ($P < 0.01$)
[1]statistical calculations were performed for each of the analyzed parameters based on – n = 120 measurements

differences in production results, dry matter intake or feed conversion efficiency between calves fed two kinds of starter concentrates whose components differed in texture and size, namely mashed or ground maize and oat grains.

It was also found in this study that the texture of the concentrate containing whole maize and oat grains affected the histological pattern and selected qualitative and morphometric parameters of the rumen and small intestine in calves (Table 4). The bull calves of experimental group were characterised by higher (by 36.4%, $P < 0.05$) weight of the small intestine, accompanied by a decrease in the circumference of its particular segments (duodenum, jejunum, ileum). The average rumen weight was comparable in all young bulls. Calves fed whole cereal grains had significantly thicker duodenal epithelium ($P < 0.01$) and jejunal mucosa ($P < 0.05$), as well as thinner jejunal epithelium, ruminal epithelium ($P < 0.01$) and cornified layer of ruminal epithelium – 17.50 vs. 33.39 μm (Table 4, Figures 1 and 2).

Microscopic examinations (male calves) showed that the rumen and small intestine, their mucosa and duodenal glands had a regular pattern (Table 5). Ruminal papillae were long and regular in shape. Moreover, intestinal villi in calves fed diets containing whole maize and oat grains were long and regular in shape and had a regular pattern, whereas in the young bulls of control group the villi were irregular and varied in length and shape, especially in the jejunum and ileum. Abundant exfoliation of the epithelial cells of duodenal villi was observed in two control calves and in one experimental calf. The same changes were recorded in the other parts of the small intestine in single calves of each group.

No significant ($P < 0.01$) effect of the physical form of rations on the weight of the reticulorumen (with

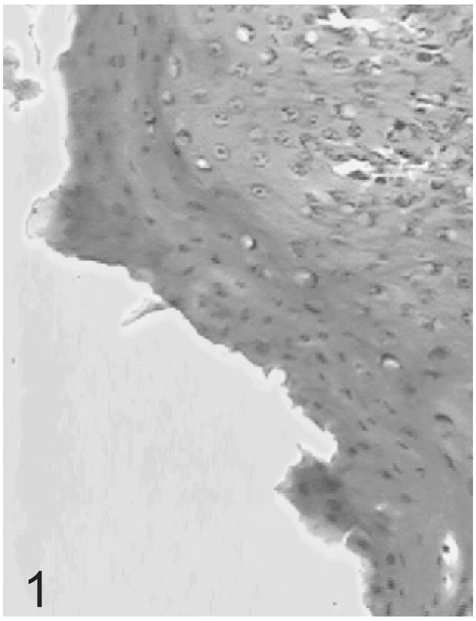

Figure 1. The abundantly keratinized ruminal epithelium of control calves fed starter concentrates containing ground cereal grains (magnification 20×)

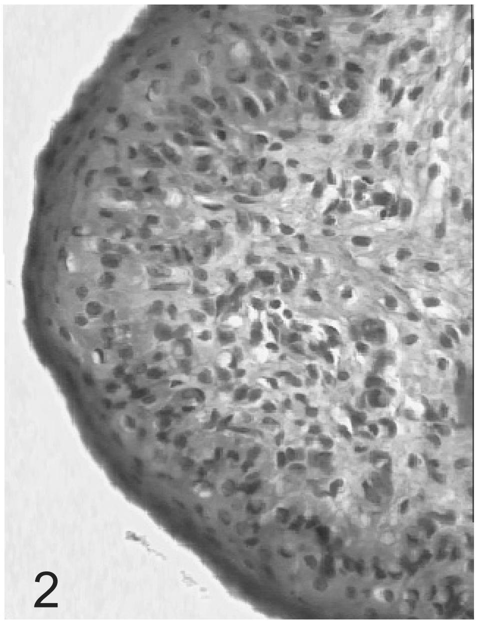

Figure 2. The ruminal epithelium of experimental calves fed concentrates containing whole maize and oat grains (magnification 20×)

or without digesta) was confirmed by Beharka et al. (1998). Nevertheless, the reticulorumen weight was slightly higher in 10-weeks-old calves fed ground cereals than in those receiving unground cereals and roughage. Greenwood et al. (1997) and Baldwin (2000) shared the opinion that an increase in the weight of ruminal walls in calves was determined by an increase in dry matter intake from solid feed. In the present study an interdependence was observed between the physical structure of the concentrate and the thickness of duodenal mucosa, duodenal epithelium, jejunal epithelium and ruminal epithelium. It should be noted that the thickness of the keratinized layer of ruminal epithelium was nearly twice higher, and therefore the thickness of ruminal epithelium was also significantly higher, in calves fed ground cereal components, in comparison with calves receiving a diet supplemented with 50% of whole maize and oat grains (33.39 vs. 17.50 µm and 127.12 vs. 97.24 µm, respectively). It seems that rations containing fine feed particles may limit the regeneration of epithelial cells, which leads to increased keratinization and – in consequence – to an increased thickness of ruminal epithelium. On the other hand, a higher proportion of larger-size particles in the ration (including whole grains) not only influences the rumen development but also causes mechanical abrasion of the epithelium, thus preventing keratinization (Beharka et al., 1998). Moreover, mechanical stimulation may increase the blood supply to the epithelium, thus enhancing the metabolic activity of the rumen and contributing to the proper development and function of the forestomach. According to Greenwood et al. (1997), the keratinization of ruminal epithelial cells may substantially intensify in calves fed finely ground concentrates. These authors suggested that fine feed particles had a greater influence on keratin formation in ruminal epithelial cells and – in consequence – on a decrease in the metabolic activity of ruminal tissues. On the other hand, Cozzi et al. (2002) reported that metabolic disorders in growing calves resulted primarily from advanced keratinization of ruminal epithelium.

Specialists differ in their opinions on the effect of feed texture on the size and growth of ruminal papillae in calves. According to Greenwood et al. (1997), the size of ruminal papillae (both length and width) decreases significantly along with an increase in the size of feed particles. In the experiment performed by these authors the proportion of branched ruminal papillae was 25% in calves fed finely ground feed and only 12% in animals given coarsely ground feed. In the present study no dif-

Table 5. Histological qualitative evaluation of the rumen and small intestine of calves

Item	Groups	
	control	experimental
Rumen		
Epithelium		
– regular pattern	+++*	+++*
Papillae		
– long and regular in shape	+++	+++
Duodenum		
Mucosa		
– regular pattern	+++	+++
Villi		
– long and regular in shape	++	+++
– short and knob-like, dilated in shape	+	absent
– abundant exfoliation of epithelial cells	++	+
Glands		
– regular pattern	+++	+++
Lymph follicles		
– regular pattern	stimulated to proliferation**	+++
Jejunum		
Mucosa		
– regular pattern	+++	+++
Villi		
– regular pattern and shape	irregular in shape	+++
– abundant exfoliation of epithelial cells	+	+
Glands		
– regular pattern	crypts stimulated to proliferation**	+++
Ileum		
Mucosa		
– regular pattern	+++	+++
Villi		
regular pattern and shape	varied length and shape	+++
– abundant exfoliation of epithelial cells	+	+
Glands		
– regular pattern	crypts stimulated to proliferate**	+++
lymph follicles		
– numerous large	+++	+++
– stimulated to proliferation**	+++	+++

*number of calves (per groups) in which a given parameter was observed

**mitotic index (the ratio between the number of cells in mitosis and 100 cells) was also determined ferences were observed between calves with respect to the appearance of ruminal papillae – all of them had a regular pattern and were long and regular in shape. Zitnan et al. (2003) and Lesmeister et al. (2004) found no relationships between the feed texture and the size of papillae in the dorsal part of the rumen. Beharka et al. (1998) observed no changes in the size of ruminal papillae in calves fed both finely and coarsely ground feed, either. In this study calves given coarsely ground feed had more regular ruminal papillae with a firm base, while the ruminal papillae of calves receiving finely ground feed were irregular, thinner and densely distributed, with a tendency towards branching. However, feeding diets containing coarsely ground components did not increase the area of nutrient absorption due to the progress of keratinization of papillae. According to Greenwood et al. (1997), the branching of ruminal papillae increases proportionally to the degree of keratinization of ruminal epithelial cells. Lesmeister and Heinrich (2004) reported that calves fed a pelleted starter diet supplemented with 33% of whole maize (WM) until 4 weeks of age had longer ruminal papillae than calves receiving dry-rolled maize (DRM) and roasted-and-rolled maize (RRM), and that the length of their papillae was similar to that observed in calves given steam-flaked maize (SFM). Physical processing of maize grains caused no changes in the width of ruminal papillae. Feeding whole maize (WM) grains to calves decreased the thickness of ruminal walls. McGavin and Morrill (1976) postulated that the histological results of the measurement of the average size of ruminal papillae may vary widely, due to the great diversity of their shapes. The above authors also pointed to the fact that the growth of ruminal papillae may be affected by decreased metabolic activity of ruminal walls, accompanied by abundant keratinization of ruminal epithelial cells.

It should be stressed that in the present experiment whole maize and oat grains contained in concentrates had a beneficial influence on the morphometric structure of the small intestine. No such results were reported by other authors. Experimental calves had long, regular and tall villi, both in the duodenum and in the other segments of the intestine, which could positively affect nutrient absorption, as confirmed by significantly higher mean daily gains (from day 31), compared to bull calves of the control group. Feeding a concentrate containing ground cereal grain to calves resulted in the occurrence of irregular villi of various shapes in the small intestine (especially in the jejunum and ileum).

Previous findings of Xu et al. (1992) revealed considerable changes in the structure of the small intestinal mucosa in calves and piglets during the first days after birth. These changes included an increased number of mitotic divisions in the cells of intestinal crypts and intensified differentiation of cells responsible for nutrient absorption (enterocytes) and intestinal mucus production (goblet cells), accompanied by a considerable increase in the small intestine weight resulting primarily from the fast mucosa growth (thickening), and in the length of intestinal villi. Intensive cell proliferation was observed within the intestinal mucosa, leading to an increase in villus height and crypt depth. As reported by Zabielski (1998) and Woliński et al. (2003), an important role is played in this process by non-nutritional components of colostrum, the so called bioactive components (hormones, bioactive peptides, immunoglobulins, lactoferrin). These components can also be found in whole milk, though in smaller quantities.

Blättler et al. (2001) demonstrated that the milk replacer (based on cow's milk) fed to newborn calves caused many undesirable changes in the structure of the small intestinal mucosa which were not observed in calves receiving colostrum and cow's milk. Studies conducted by Niwińska (2005) on bull calves (from 7 to 36 days of age) also showed that whole milk (as compared with milk replacer) had a beneficial influence on duodenum weight, length of intestinal villi, submucosa thickness, and daily weight gains ($P < 0.05$).

An increased concentration of solid feed in the ration for older calves also causes numerous histological and biochemical changes in the rumen and small intestine, as confirmed by the present results. In most cases, these changes are a consequence of the lowered digestive and absorptive capacity of intestines. This leads to the atrophy of intestinal villi through cell losses, increases the crypt depth and enhances the cell proliferation in the intestinal mucosa (Pluske et al., 1997). Zitnan et al. (2003) proved that diet composition affected selected morphometric parameters of the small intestine in bull calves aged 5 months. Intensively fed animals (concentrate accounted for 73% of dietary dry matter) were characterized by higher intestinal villi in the duodenum ($P = 0.026$) and in the jejunum ($P = 0.052$), in comparison with extensively fed animals (wilted silage accounted for 83%, and concentrate mixture for 5.6% of dietary dry matter). There were no significant differences in the depth of crypts, however, the crypts of the intensively reared animals were somewhat deeper.

CONCLUSIONS

During the first 30 days, higher daily gains were recorded in calves fed a diet containing ground cereal components. Over the entire experimental period, the supplementation of whole cereal grains to a diet allowed to increase the average daily gains of calves in the experimental group, in comparison with the control group. The addition of whole maize and oat grains to a diet positively affected selected morphometric parameters of the rumen and small intestine in calves, which was reflected in a considerable improvement in production results during the first 90 days of rearing. The obtained results indicate that it is recommended to supplement whole maize and oat grains to diets for calves, starting from the second month of life.

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