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Effects of different types of solid feeds on health status and performance of Swiss veal calves. I. Basic feeding with milk by-products

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Summary

The objective of this study was to identify a suitable alternative to the current practice of complementing the feeding of milk by-products with straw. The influence of 5 different types of solid feeds on health and performance of Swiss veal calves was investigated in 2 production cycles of 200 veal calves each with a mean initial age of 40 days (d). The calves were housed in groups of 40 in stalls with outside pen. Liquid feeding consisted of a milk by-product combined with an additional skim milk powder *ad libitum*. Groups were assigned to 1 of the 5 following experimental solid feeds provided *ad libitum*: mix (composition: soy flakes, corn, barley, wheat, oat, barley middling, plant oil, molasses), whole plant corn pellets, corn silage, hay, and wheat straw as control. Daily dry matter intake per calf averaged 2.25 kg of the liquid food, 0.16 kg of straw, 0.33 kg of mix, 0.47 kg of corn silage, 0.38 kg of corn pellets, and 0.39 kg of hay. No significant differences ($P > 0.05$) among groups were found in calf losses that amounted to 4.8 % (68 % because of gastrointestinal disorders). Four percent of the calves were slaughtered prematurely. Daily doses of antibiotics were higher in the mix (36.9 d, $P < 0.01$) and in the corn silage groups (35 d, $P < 0.01$) compared to control. Compared to the 4 other groups, calves of the straw group showed the highest prevalence of abnormal ruminal content (73 %, $P < 0.05$), of abnormal ruminal papillae (42 %, $P < 0.05$), of abomasal fundic lesions (13.5 %, $P < 0.1$), and the lowest number of chewing movements per bolus (45, $P < 0.05$). The hemoglobin concentration averaged 85 g/l at the beginning and 99 g/l at the end of the fattening period with no significant differences among groups ($P > 0.1$). The duration of the fattening period averaged 114 d, slaughter age 157 d, and carcass weight 122 kg. The average daily weight gain (ADG) was highest in the control group straw (1.35 kg), and lowest in the hay group (1.22 kg, $P <$

Der Einfluss von Festfutter auf die Gesundheit und Leistung von Schweizer Mastkälbern. I. Milchnebenprodukte als Grundfutter

Das Ziel dieser Studie war es, eine geeignete Alternative zur bisherigen Strohbeifütterung von Mastkälbern zu finden. Während zwei Mastdurchläufen mit jeweils 200 Schweizer Mastkälbern mit einem Einstallalter von 40 Tagen, wurde der Einfluss von 5 verschiedenen Raufuttern auf deren Gesundheit und Leistung untersucht. Die Kälber wurden in 40er Gruppen mit frei zugänglichem Auslauf gehalten. Die Flüssigfütterung bestand aus einem Milchnebenprodukt ergänzt mit einem Milchpulver und wurde *ad libitum* verabreicht. Die Gruppen wurden jeweils einem der folgenden experimentellen Futtermittel zugeteilt: Mix (Zusammensetzung: Sojaflocken, Mais, Gerste, Weizen, Hafer, Gerstenfuttermehl, Pflanzenöl, Melasse), Ganzpflanzen-Maiswürfel, Maissilage, Heu und Weizenstroh als Kontrollgruppe. Die tägliche Trockensubstanzaufnahme betrug pro Kalb durchschnittlich 2.25 kg für das Flüssigfutter, 0.16 kg für Stroh, 0.33 kg für Mix, 0.47 kg für Maissilage, 0.38 kg für Maiswürfel und 0.39 kg für Heu. Bezüglich der Kälberverluste, welche total 4.8 % betrugen (68 % wegen gastrointestinalen Störungen), gab es keine signifikanten Unterschiede zwischen den Gruppen. Vier Prozent der Kälber mussten frühzeitig geschlachtet werden. Kälber aus der Mix- und der Maissilage-Gruppe wurden im Vergleich zur Kontrollgruppe Stroh länger antibiotisch behandelt (Mix-Gruppe 36.9 Tage, $P < 0.01$, Maissilage-Gruppe 35 Tage, $P < 0.01$). Im Vergleich zu den anderen 4 Gruppen wiesen Kälber aus der Strohgruppe am häufigsten abnormalen Panseninhalt auf (73 %, $P < 0.05$), sie hatten am häufigsten abnormale Pansenzotten (42 %, $P < 0.05$), am meisten Labmagenläsionen im Fundusbereich (13.5 %, $P < 0.1$) und sie zeigten das schlechteste Wiederkauverhalten (45 Schläge pro Bolus, $P < 0.05$). Die mittlere

0.01). The number of carcasses classified as C, H, and T (very high to medium quality) was lower in the hay group compared to straw ($P < 0.01$). No significant differences between groups were found in meat color ($P > 0.1$): 73 % of the carcasses were assessed as pale (267/364), 18 % as pink (66/364), and 9 % (31/364) as red. The results reveal that whole-plant corn pellets are most consistent with an optimal result combining the calves' health and fattening performance. Therefore, it can be recommended as an additional solid feed for veal calves under Swiss conditions.

Keywords: *ad libitum* feeding, health, performance, solid feeds, veal calves

Hämoglobinkonzentration lag bei 85 g/l zu Beginn und bei 99 g/l am Ende der Mast, wobei es keine signifikanten Unterschiede zwischen den Gruppen gab ($P > 0.1$). Die durchschnittliche Mastdauer betrug 114 Tage, das durchschnittliche Schlachtalter 157 Tage und das mittlere Schlachtgewicht lag bei 122 kg. Die durchschnittliche Tageszunahme war bei den Kälbern aus der Strohgruppe am höchsten (1.35 kg) und bei den Kälbern aus der Heugruppe am tiefsten (1.22 kg, $P < 0.01$). Die Anzahl an gut bis sehr gut klassifizierten Schlachtkörpern (T bis C) war in der Heugruppe tiefer im Vergleich zur Strohgruppe ($P < 0.01$). Betreffend Fleischfarbe konnten keine signifikanten Unterschiede zwischen den Gruppen festgestellt werden ($P > 0.1$): 73 % der Schlachtkörper wurden als hell eingestuft (267/364), 18 % als rosa (66/364) und 9 % als rot (31/64). Die vorliegenden Resultate zeigen, dass Ganzpflanzen-Maiswürfel dem Anspruch an Gesundheit und Leistung des Mastkalbes am ehesten gerecht werden. Ganzpflanzen-Maiswürfel können deshalb als Alternative zur Strohbeifütterung von Mastkälbern unter Schweizer Bedingungen empfohlen werden.

Schlüsselwörter: *ad libitum* Fütterung, Gesundheit, Leistung, Festfutter, Mastkälber

Introduction

Straw is a common and inexpensive source of raw fibers being used as a solid supplement to liquid feeding of veal calves. However, straw as the only solid feed is suspected to have a detrimental effect on the calves' health status since it has been associated with an increased incidence of abomasal lesions (van Putten, 1982; Welchman and Baust, 1987; Mattiello et al., 2002; Bähler et al., 2010a), non- or poor development of the ruminal mucosa (Mattiello et al., 2002), and lower hemoglobin concentrations at slaughter as compared to calves receiving hay or suckler calves maintained on pasture (Egger and Bourgeois, 1993; Thielscher, 1994). In order to improve animal welfare, straw as the only additional solid feed will be banned in Switzerland by September 1, 2013 and *ad libitum* feeding of an alternative roughage source is mandatory (Tierschutzgesetz, 2005; Tierschutzverordnung, 2008). To fill this gap, further research into the economic and welfare implications of alternative solid feeds in combination with *ad libitum* liquid feed is needed.

The objective of the present study was to provide a rational basis for the selection of a suitable solid feed which complies with the calves' physiology and the demands of the market concerning performance and, therefore, to assess the effect of 5 types of solid feeds in addition to a liquid diet on health and performance of Swiss veal calves in an *ad libitum* feeding system.

Animals, Material and Methods

Animals

The investigation included 2 production cycles (PC1 and PC2) each with 200 Swiss veal calves (Tab. 1). Production cycle 1 lasted from July to November 2009, PC2 from November 2009 to March 2010. Slaughtering decision was made by the farmer when calves reached a body weight (BW) of 220 to 240 kg.

Housing

Calves were housed on a commercial farm in a single building with 5 stalls. The stalls had concrete floors and were separated by wooden walls of 1.8 m height. Space allowance amounted to 2 m^2/calf and wheat straw was used as bedding material. Each stall was associated with a corresponding outside pen of 60 m^2, of which 20 m^2 were sheltered and bedded with wheat straw. After each PC, barns and outside pens were thoroughly cleaned with high-pressure water without detergent.

Table 1: Basic data on 400 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Feeding treatment	No. of calves	Initial age (days)	Initial BW[1] (kg)	Sex (%)		Breed (%)		
				F[2]	M[3]	Dairy[4]	Cross	Beef[5]
				PC1/PC2	PC1/PC2	PC1/PC2	PC1/PC2	PC1/PC2
Wheat straw (control)	80	40.3 ± 13.1	74.7 ± 8.1	15/12.5	85/87.5	90/94.9	10/2.6	0/2.6
Mix[6]	80	37.3 ± 13.6	76.5 ± 10.3	30/12.5	70/87.5	71.1/81.6	21.1/10.5	7.9/7.9
Corn silage	80	40.6 ± 15.5	73.9 ± 7.0	25/0	75/100	85.3/94.9	14.7/2.6	0/2.6
Corn pellets	80	41.3 ± 12.6	69* ± 8.6	22.5/12.5	77.5/87.5	92.5/100	2.5/0	5/0
Hay	80	41.4 ± 14.4	70.4* ± 6.9	2.5/7.5	92.5/92.5	100/97.5	0/0	0/2.5

* Within columns, means are significantly different from straw ($P < 0.05$)
[1] Body weight
[2] Female
[3] Male
[4] Dairy breeds = Swiss Braunvieh, Holstein, Red Holstein, Swiss Rotfleck
[5] Beef breeds = Limousin, Montbéliard, Normande, Simmental
[6] Composition: soy flakes (33 %), corn (10 %), barley (10 %), wheat (10 %), oat (3 %), barley middling (30 %), plant oil (1 %), molasses (3 %)

Feeding

The basic *ad libitum* feeding plan of calves included a liquid milk by-product and a skim milk powder (Amobolac and Gefumilk, Gefu Oberle AG, Rickenbach) mixed with water (Tab. 2). This liquid diet was dispensed from an automatic feeding system (Küng Kombimat 1000, Gefu Service AG, Rickenbach) equipped with 4 artificial teats per stall (for feeding plan see Tab. 3). After the initial group medication, calves received a premix (Gefu-lacto, Gefu Oberle AG, Rickenbach) to support the gastrointestinal flora, and additional iron and vitamin supplementation was provided by 2 other premixes (Gefu-fer and Gefu-vit, Gefu Oberle AG, Rickenbach, Tab. 4).
Each group of 40 calves was assigned to 1 of the 5 following experimental feeding regimens: wheat straw (control), mix (composition: soy flakes, corn, barley, wheat, oat, barley middling, plant oil, molasses), corn silage, whole plant corn pellets, and hay (for contents of solid feeds see Tab. 5). The amount of solid feeds was weighed before provision and noted daily on a protocol. Feed leftovers were weighed once weekly and included in the calculations. Calves had free access to water and minerals (Homin and Minalo, Gefu Oberle AG, Rickenbach, see Tab. 4).

Health status

Clinical examination and medical treatment

Calves were weighed, underwent clinical examination within 5 days after arrival, and were treated immediately if they showed any sign of illness. Health status was assessed daily by the farmer and if necessary, individual medication was administered. In addition, calves were observed weekly by the first author during the first 8 weeks of fattening and every 2 weeks thereafter. Conspicuous calves were examined and the signs of illness summarized as follows: nasal and eye discharge, respiratory sounds determined by lung auscultation, dyspnea, and coughing were added up to the variable Respiratory Signs (RS) with a maximum score of 5 for a calf which showed all of these clinical signs; diarrhea, bloating, and abnormal abdominal swinging auscultation

Table 2: Contents of milk by-product and supplementary skim milk powder fed to 400 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Item	Milk by-product[1]			Skim milk powder[2]		
	week 1	week 9	week 17	week 1	week 9	week 17
Lactose, g/kg DM	407.5	427.5	429.5	355.5	373.5	365
Iron, mg/kg DM	< 2	< 2	< 2	153.2	42.9	44
Crude ash, g/kg DM	47.4	49.9	49.1	78.9	163.8	85.1
Crude fat, g/kg DM	208	211	190	109.5	153.5	125.5
Crude protein, g/kg DM	197.5	189	197.3	260	206.8	205.8
Dry matter (DM), g/kg	328.5	331	334	951	956	956.5

[1] Amobolac (Gefu Oberle AG, Rickenbach, Switzerland)
[2] Gefumilk (Gefu Oberle AG, Rickenbach, Switzerland)

Table 3: Liquid feeding plan for the 400 veal calves used in this study.

Week	l/calf/day	l Amobolac (330g/kg DM[1])	Gefumilk (g)	DM/kg liquid feed (g)	DMI[2]/calf/d
1	11	0	90	90	0.9
2	12	0.2	30	30	1.15
3	13	0.25	30	30	1.46
4	14	0.29	30	30	1.76
5	15	0.33	30	30	2.08
6	15	0.36	30	30	2.23
7	15	0.42	20	20	2.38
8	15	0.45	20	20	2.53
9	15	0.48	20	20	2.68
10	15	0.50	20	20	2.78
11	15	0.52	20	20	2.87
12	15	0.52	20	20	2.87
13	15	0.52	20	20	2.87
14	15	0.52	20	20	2.87
15	15	0.52	20	20	2.87
16	15	0.52	20	20	2.87
17	15	0.52	20	20	2.87

[1] Dry matter
[2] Dry matter intake

Table 4: Contents of the feeding supplements fed to 400 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Item	Homin g/kg DM[1]	Minalo g/kg DM	Gefu-lacto g/kg DM	Gefu-vit g/kg DM	Gefu-fer g/kg DM
Vit A (I.E.)	100'000'000	600'000		1'500'000	
Vit. D (I.E.)	200'000	120'000		150'000	
Vit. E (mg)	3'500	1'500		10'000	20'000
Vit. C (mg)				12'000	
Calcium (g)	120	160			
Phosphor (g)	60	60			
Magnesium (g)	30	40			
Natrium (g)	60	110			
Iron (mg)	200	200	5	5	20'300
Selenium (mg)	20	8		60	
Manganese (mg)	500	800		4'800	
Copper (mg)	200	50		150	2'020
Zinc (mg)	2'000	720		3'000	22
Cobalt (mg)	20	3			
Jodine (mg)	20	6			
Navetin Lactobac. (Mio CFU[2])			1'500		

[1] Dry matter
[2] Colony Forming Units

were added up to the variable Digestive Signs (DS) with a maximum score of 3 per calf. Thickened umbilical cord, umbilical hernia, and inflammation were added up to the variable umbilical abnormalities with a maximum score of 3 per calf. Coat signs included alopecia, ectoparasites, and trichophytosis (maximal score 3). The scores for the different clinical signs were added and the sums compared among feeding groups. The total score for individual variables exceeded the number of examinations because diseased calves typically showed a combination of several clin-

Table 5: Contents of solid feeds fed to 400 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Item	Wheat straw (control)	Mix[1]	Corn silage	Corn pellets	Hay
Dry matter (g/kg wet weight)	906–915.5	887.7–895.7	312.5–416	879–895.5	870–897.5
Crude protein (g/kg DM[2])	31–35.8	205.1–210.8	73.3–83.8	59.8–60.8	66–73.3
Crude ash (g/kg DM)	51.9–58.3	37.6–38.8	28.7–34.5	27.7–28.6	51.8–54
Crude fiber (g/kg DM)	413–425.5	61.7–73.8	185.3–220.5	188–188.6	306–333.5
ADF[3] (g/kg DM)	476–487	88.5–104	206.8–249.3	212–224.8	342.3–367
NDF[4] (g/kg DM)	743.3–756.5	213.7–242.3	376.2–452	375.7–397.3	572.5–623.3
Starch (g/kg DM)	< 2	239.7–262.8	280.8–333	321.5–343.8	< 2
Iron (mg/kg DM)	60.5–87.5	42.3–45	59–74.3	71.3–77.8	57.5–130.3

[1] Composition: Soy flakes (33 %), corn (10 %), barley (10 %), wheat (10 %), oat (3 %), barley middling (30 %), plant oil (1 %), molasses (3 %)
[2] Dry matter
[3] Acid detergent fiber
[4] Neutral detergent fiber

ical signs. Following clinical examination, all calves were injected with 10 mL of selenium (Tocoselenit, Graeub AG, Bern) and 5 mL of iron-hydroxide-dextrane-complex Fe^{3+} (Ferriphor 20 %, Graeub AG, Bern). In addition, all calves were group-medicated prophylactically by the automatic feeding system in a daily dosage of 24 mg chlortetracyclini hydrochloridum/18 mg spiramycinum per kg BW (SK-60, Biokema SA, Lausanne) for 10 to 14 days.

Ruminating behavior

The ruminating behavior of the calves was assessed weekly between 1 and 2 p.m. and the numbers of chewing movements per calf counted for a minimum of 2 and a maximum of 5 randomly selected calves per group.

Hematological status

Blood samples were obtained from the jugular vein in weeks 1 and 7 of the fattening period. A third blood sample was taken at the slaughterhouse immediately after captive-bolt stunning by dissecting the calves' left jugular vein and avoiding contact of blood with exposed tissues.

Abomasal lesions

The abomasa of the calves were labeled with ear tags, and within 4 h from slaughter, opened along the great curvature and rinsed with water at the Division of Veterinary Anatomy, University of Bern. Lesions of the abomasal lining were assessed macroscopically in a double-blinded procedure according to Bähler et al. (2010a).

Ruminal content, pH and mucosa

At the slaughterhouse, rumina were dissected along the dorsal line, and the consistency of ruminal content was evaluated according to Cozzi et al. (2002), with the following modifications: Rumino-reticula were not weighed, the presence or absence of foreign bodies was noted, ruminal content was considered normal if there was a humid and compact mass of fibers (maximum length 1 cm), but abnormal when either the consistency was firm, pasty or liquid or if unusual contents were present. After dissecting the rumen, the pH of the ruminal content was measured with a pH meter (Mettler Toledo, Greifensee, Switzerland). The length of the papillae was assessed visually according to Cozzi et al. (2002). Papillae shorter than 2 mm were categorized as insufficient according to Morisse et al. (2000).

Calf losses and necropsy

Animals that died during the fattening period were subjected to necropsy at the Institute of Animal Pathology, University of Bern within 1 day after death. The cause of death was determined by gross inspection and, if necessary, by histopathologic evaluation (7/19 cases).

Growth performance and carcass quality

At the slaughterhouse (FF Frischfleisch AG, Sursee), carcass quality was scored according to the Swiss standard. Assessment included carcass conformation (C, H, T, A, and X, where C represents the best carcass conformation and X the lowest), degree of fat cover (1 = low fat cover, 4 = high fat cover), and color of the meat (pale, pink or red), which was assessed visually by a single expert. The weight at the end of the fattening period (slaughter weight, SW) was calculated based on carcass weight (hot carcass weight HCW = 56 % of BW). The average daily weight gain (ADG) was computed from the difference between the SW and the BW at the beginning of the fattening period divided by the duration of the PC in days. Additionally, feed gain ratio was calculated by dividing average daily dry matter intake and average daily weight gain.

Laboratory analyses

Blood samples were transported at 4 °C and processed within 4 h. Hemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin con-

centration (MCHC), and concentration of hemoglobin per reticulocyte (CHr) were determined using an automatic hematology system (ADVIA 120, Siemens Healthcare Diagnostics, Germany). Samples of solid feeds were taken weekly, stored at –20 °C, and pooled prior to analysis at the end of each PC. All analyses were done at the Swiss Federal Research Station ALP in Posieux, Switzerland. Prior to laboratory analysis, solid feed samples were grounded to pass a 1.0 mm sieve (Brabender mill #880804, Brabender, Germany). Samples of liquid feed were taken and analyzed at weeks 1, 8, and 16 and lyophilized prior to analysis. The analyses of solid feeds included contents of dry matter (DM), acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, crude fat, crude fiber, crude protein (CP), iron, and lactose. Contents of DM were quantified gravimetrically (3 h at 105 °C). Total ash was determined by incineration at 550 °C for 4 h. The ADF was analyzed according to AOAC (2010) and was determined without residual ash after incineration at 500 °C for 1 h. Analysis of NDF was based on the method of Mertens (2002) with the addition of heat-stable amylase and results were expressed without residual ash. Starch was determined with a Polarimeter (241MC Polarimeter, Perkin-Elmer, Waltham, MA, USA). Crude fat was determined gravimetrically after hydrolysis and extraction with petrol ether. Determination of crude fiber was made gravimetrically according to the ANKOM-System (ANKOM 200/220 Fiber Analyzer, Ankom Technology Corporation Inc., Fairport, NY, USA). Analysis of iron was based on inductively coupled plasma emission spectrometry (ICP-OES Optima 7300 DV, Perkin-Elmer, Waltham MA, USA). The contents of lactose in liquid milk by-product and skim milk powder were determined by an enzymatic method using b-galactosidase and hexokinase and a subsequent quantification by differential pH technique (EFA Microlab plus pH-Differential-meter, Hamilton Bonaduz AG, Switzerland). The CP was calculated as 6.25 x total N concentration, whereas analysis of total N concentration was based on the method of Kjeldahl (AOAC, 2010).

Statistical analyses

Statistics were generated with the software NCSS 2007 (NCSS, Kaysville, UT, USA). For analyses, the production cycles PC1 and PC2 were pooled and the effect of feeding treatment statistically evaluated. Statistical comparisons of the effect of feeding treatments on continuous outcomes were performed by multivariate models with the NCSS procedure Mixed Models. In these models, the effect of feeding treatment was corrected for the covariate production cycle. Potential interactions between feeding treatment and production cycle were also explored. The models had the general form:

$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$

Where i is the number of feeding treatments (5), j is the number of production cycles (2), and k the number of calves with data on the relevant outcome. The model expresses the value of the outcome, Y, as the sum of five components:

- μ the mean
- a_i the contribution of the i^{th} level of feeding treatment
- b_j the contribution of the j^{th} level of production cycle
- $(ab)_{ij}$ the interaction of the i^{th} level of feeding treatment and the j^{th} level of production cycle
- e_{ijk} the contribution of the k^{th} individual (error)

In addition to the production cycle, the effect of the potential co-factors initial age, initial Hb, sex, and breed on the outcome was explored in the multivariate models. Initially, all factors were included in the models. Subsequently, the non-significant ($P > 0.05$) factors were removed with a stepwise backward variable selection procedure. In the models, straw was used as a reference group. In addition, differences between the other feeding groups are reported. For these multiple group comparisons, Bonferroni adjustment of α-values was applied. This resulted in a level of significance of $\alpha = 0.005$, because a total of 10 group comparisons was possible. For categorical outcome variables, multivariate logistic regression analysis was performed to analyze the effect of feeding treatment, production cycle and potential co-factors on the outcome.

Data about medical treatments were entered in an Access database according to Bähler et al. (2010b) and variables were calculated on group and individual levels. For analysis, the days under antibiotic treatment per group were counted and compared. Each treatment with a commercial drug containing antibiotics or chemotherapeutics was considered to be one daily dose of antibiotics (DDA).

Results

The data for the 16 calves which were slaughtered prematurely because of injury, acute ruminal bloat or chronic otitis were discarded from the processed data set because of incompleteness. Only corresponding data subsets from the first examination such as weight, breed, sex and the results of the first blood analysis as well as the data regarding ruminating behavior remained in the analyses. The fluctuations in sample size of some variables tested (abomasal lesions, ruminal content, ruminal pH, growth performance, and carcass quality) were due to technical problems in the slaughterhouse. Where no *P*-values are mentioned, no significant difference to the straw group was detected.

Feed intake and analyses

Statistical comparison of intake among feeding treatments was not possible, because an average of consumption value was calculated on group level and only one value per PC and feeding group was available. The daily dry matter intake (DMI) of liquid milk by-product aver-

Table 6: Daily doses of antibiotics (DDA[1]) administered to 384 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Item	Wheat straw (control)	Mix[2]	Corn silage	Corn pellets	Hay
DDA group	31.5 ± 0	35 ± 0	32.5 ± 0	32 ± 0	32 ± 0
DDA individual	2.0 ± 2.3	1.9 ± 2.6	2.2 ± 2.4	1.6 ± 2.2	1.6 ± 2.1
DDA total	33.4 ± 5.9	36.9* ± 9.1	35.0* ± 6.0	33.5 ± 6.1	33.7 ± 3.2

[1] DDA = each treatment with a commercial drug containing antibiotics or chemotherapeutics is considered to be one daily dose of antibiotics
[2] Composition: Soy flakes (33 %), corn (10 %), barley (10 %), wheat (10 %), oat (3 %), barley middling (30 %), plant oil (1 %), molasses (3 %)
* Within rows, means are significantly different from straw ($P < 0.05$)

aged 2.09 kg in the straw group, 1.85 kg in the mix group, 1.8 kg in the corn silage group, 1.79 kg in the corn pellets group, and 1.92 kg in the hay group. The daily DMI of skim milk powder was 0.38 kg in the straw group, 0.36 kg in the mix group, 0.37 kg in the corn silage group, 0.34 kg in the corn pellets group, and 0.36 kg the hay group. The daily DMI of the different solid feeds was 0.16 kg for straw, 0.30 kg for mix, 0.17 kg for corn silage, 0.34 kg for corn pellets, and 0.34 kg for hay.

Clinical examination

At the beginning of the fattening period, 73 % of the calves (292/400) showed at least 1 pathological finding, and significant differences among groups were not established ($P > 0.1$). Umbilical abnormalities were present in 49.5 % (198/400) of the calves, 45 % (179/400) showed at least one RS, 33.5 % (134/400) were in a poor body condition, 15.5 % (62/400) showed coat signs, 5.5 % (22/400) had DS, and 5.5 % (22/400) had an elevated body temperature. At the weekly examinations, a total of 135 individual clinical examinations were performed, because the calves appeared conspicuous in the group observation. In these examinations, RSs were found most frequently (total score of 270). Further findings included elevated body temperature with a score of 71, reduced general condition with a score of 45, poor body condition with a score of 30, digestive signs with a score of 4, and an umbilical abnormality with a score of 1. No significant differences among groups were detected.

Medical treatment

Each feeding group was medicated with antibiotics at least 3 times in each PC. In addition to the therapeutics administered at group level, 47 % (181/384) of the calves were treated individually at least once. The combination of individual treatment and group therapy resulted in a mean total DDA (± standard deviation SD) per calf of 34.5 ± 6.43 (Tab. 6). Calves of the mix and corn silage groups were treated for significantly more days than calves of the control group straw ($P < 0.01$) and this effect remained stable after correction for the significant cofactor PC in a logistic regression model (Tab. 7). The mix group had significantly more DDA than the corn pellet, corn silage and hay group, and the corn silage group more than the corn pellet and hay group ($P < 0.005$). There was a significant interaction between feeding group and PC ($P < 0.01$, Fig. 1).

Table 7: Final multivariable regression model for the effect of feeding treatment and production cycle on daily doses of antibiotics administered to 384 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Variable	Group comparison	F-ratio	Regression coefficient	95 % confidence interval	P-value
Intercept			28.0	27.3–28.7	< 0.001
Feeding group		15.2			< 0.001
	Mix vs. straw		0.13	−0.86–1.11	0.80
	Corn pellets vs. straw		−0.1	−1.08–0.88	0.84
	Corn silage vs. straw		1.48	0.49–2.46	0.003
	Hay vs. straw		3.1	2.12–4.08	< 0.001
Production cycle		487.8			< 0.001
	PC2 (winter) vs. PC1 (summer)		11.0	10.0–12.0	< 0.001
Interaction feeding group*production cycle		79.2			< 0.001
	Mix*PC2[1]		6.53	5.14–7.91	< 0.001
	Corn pellets*PC2		0.58	−0.81–1.96	0.42
	Corn silage*PC2		−0.33	−1.71–1.06	0.07
	Hay*PC2		−6.0	−7.39- −4.61	< 0.001

[1] Production cycle 2 (winter)

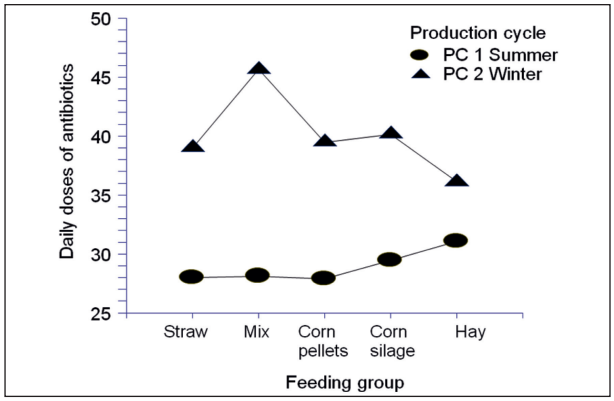

Figure 1: Daily doses of antibiotics administered to 384 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

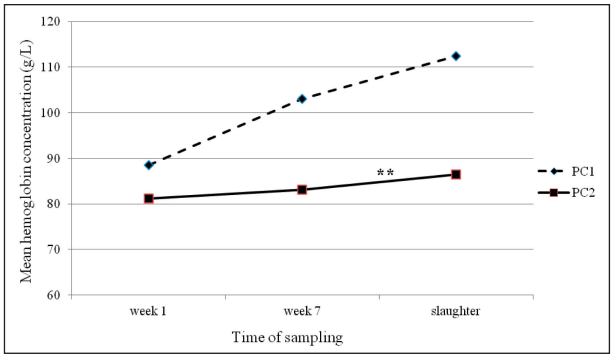

Figure 2: Development of mean hemoglobin concentration of 338 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system during PC1 (summer) and PC2 (winter).
** $P < 0.001$, referred to mean values of PC1 and PC2

Ruminating behavior

The number of ruminating movements per feeding bolus (± SD) averaged 45 ± 13.3 in the straw group, 52 ± 11.9 in the mix group ($P < 0.05$), 53 ± 13.0 in the corn silage group ($P < 0.05$), 57 ± 13.8 in the corn pellets group ($P < 0.01$), and 62 ± 12.5 in the hay group ($P < 0.01$). All feeding groups had significantly more ruminating movements than the straw group. Calves in the hay group had significantly more movements than calves in the mix and corn silage groups ($P < 0.005$).

Hematological status

Over all feeding treatments and samples, Hb concentration (± SD) averaged 92 ± 15.0 g/L, PCV 0.26 ± 4.0 L/L, MCV 27.2 ± 3.5 fL, MCH 9.4 ± 1.4 pg, MCHC 347 ± 10.3 g/L, and CHr 14.1 ± 1 pg. Blood parameters at slaughter did not reveal any significant differences among groups, whereas in weeks 1 and 7 some significant differences without clinical relevance were established. Calves of PC1 showed a higher concentration and increase of hemoglobin than those of PC2 (Fig. 2).

Abomasal lesions

The overall prevalence of mucosal lesions was 73 % (251/346) in the pylorus and 7 % (25/358) in the fundus region. Calves of the straw group showed a trend towards a higher prevalence of fundic lesions ($P < 0.1$) in comparison to the other 4 groups (Fig. 3).

Ruminal content, pH and mucosa

The ruminal contents were assessed in 358 calves. Contents of 176 rumina (49 %) were considered normal. Abnormal ruminal content was noted in 71.8 % (53/74) of the calves in the straw group, 61.8 % (42/68) in the mix group (ANOVA $P > 0.05$ compared to straw), 36.8 % (25/68) in the corn silage group ($P < 0.01$), 27 % (20/74) in the corn pellets group ($P < 0.01$), and 56.8 % (42/74) in the hay group ($P > 0.05$). The results of the final multivariable logistic regression model are presented in Table 8. Corn pellets, corn silage and hay resulted in a significantly decreased odds of abnormal ruminal content compared to straw feeding. The mix group differed significantly from the corn silage and corn pellets group, and the corn pellets group differed significantly from the hay group ($P < 0.005$). Calves with a higher Hb level at the beginning of the fattening period had a lower risk of having abnormal

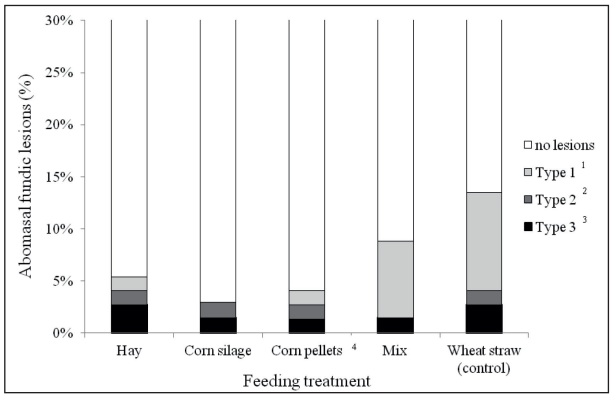

Figure 3: Distribution of macroscopic abomasal lesions in the fundic part of 358 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system, $P > 0.05$.
[1] Superficial erosions with minimal mucosal defects and mucosal discolorations
[2] Deeper erosions, the center of the lesions being clearly depressed
[3] Craters with a superficial coating, apparent loss of tissue, and central depression
[4] Composition: Soy flakes (33 %), corn (10 %), barley (10 %), wheat (10 %), oat (3 %), barley middling (30 %), plant oil (1 %), molasses (3 %)

Table 8: Final multivariable logistic regression models for the effect of feeding treatment, production cycle and significant co-factors on ruminal content and rumen papillae of 358 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Model	Variable	Group comparison	Odds ratio	95 % confidence interval	P-value
Abnormal ruminal content	Intercept		13.6	3.8–48.5	< 0.001
	Feeding group	Mix vs. straw	0.74	0.37–1.50	0.41
		Corn pellets vs. straw	0.16	0.08–0.32	< 0.001
		Corn silage vs. straw	0.24	0.12–0.48	< 0.001
		Hay vs. straw	0.49	0.24–0.97	0.04
	Production cycle	PC2 (winter) vs. PC1 (summer)	0.72	0.47–1.13	0.15
	Initial hemoglobin	Continuous (g/l)	0.98	0.97–0.99	0.005
Insufficient rumen papillae	Intercept		0.58	0.34–0.99	0.046
	Feeding group	Mix vs. straw	0.45	0.22–0.92	0.029
		Corn pellets vs. straw	0.13	0.05–0.33	< 0.001
		Corn silage vs. straw	0.23	0.10–0.51	< 0.001
		Hay vs. straw	0.30	0.14–0.63	0.002
	Production cycle	PC2 (winter) vs. PC1 (summer)	1.62	0.96–2.73	0.068

rumen content. No difference was observed between the two PCs. The most frequent abnormal finding was liquid content in 79.1 % of the anomalous cases (144/182).

Ruminal pH was determined in 341 calves. The pH of the ruminal liquid (± SD) averaged 6.54 ± 0.25 in the straw group, 6.46 ± 0.31 in the mix group (ANOVA $P > 0.05$ compared to straw), 6.44 ± 0.28 in the corn silage group ($P < 0.05$), 6.37 ± 0.31 in the corn pellets group ($P < 0.01$), and 6.59 ± 0.39 in the hay group ($P > 0.05$). All groups except the hay group differed significantly from the straw group. The mix, corn pellets and corn silage groups differed significantly from the hay group ($P < 0.005$), but not from each other. Ruminal pH was higher in winter (PC2), and in calves with a higher Hb at the beginning of the fattening period as the multivariable regression model showed.

A total of 358 rumina were evaluated. Papillae of 281 rumina (78.5 %) were considered adequate. Insufficiently developed papillae were observed in 41.9 % (31/74) of the calves in the straw group, 25 % (17/68) in the mix group ($P < 0.05$), 14.7 % (10/68) in the corn silage group ($P < 0.01$), 6.8 % (5/74) in the corn pellets group ($P < 0.01$), and 18.9 % (14/74) in the hay group ($P < 0.01$). The final multivariable logistic regression model is presented in Table 8. Compared to the straw group, all other groups had a decreased odds of having insufficient papillae. Among the other feeding groups, no significant differences were found after applying Bonferroni correction ($\alpha = 0.005$). No significant difference was observed among the two PCs.

Calf losses and necropsy

In total, calf losses (CL) amounted to 4.8 % (19/400), and no significant differences among groups were observed ($P > 0.5$). Thirteen calves died and 6 calves were euthanized during the fattening period. In the majority of cases (68 %, 13/19), gastro-intestinal diseases were established as the cause of death. The most frequent diagnoses were ruminal bloat (6/19) and perforated abomasal ulcers (4/19). In one case each, further necropsy findings included bacterial septicemia, intestinal volvulus, enterocolitis, bacterial bronchopneumonia, neck trauma, septic carpitis, and miscellaneous findings combined (ulcerative abomasitis, peritonitis, rumenitis). In 2 cases, the cause of death could not be determined. Four percent of the calves (16/400) were slaughtered prematurely because of injury, acute ruminal bloat or chronic otitis.

Growth performance and carcass quality

Based on the 364 calves slaughtered, slaughter age (± SD) averaged 157 ± 14.2 days, carcass weight 122 ± 13.8 kg, and the duration of the fattening period 114 ± 10.1 days. The conformation of most carcasses (69.8 %, 254/364) yielded a medium meat quality (T). Furthermore, 1.9 % (7/364) were assessed as C, 4.1 % (15/364) as H, 19.5 % (71/364) and 4.7 % (17/364) as low A and X, respectively. The majority of carcasses (56.6 %, 206/364) had a fat cover of the favored degree 3, 26.4 % (96/364) of degree 2, 11.5 % (42/364) of degree 1, and 5.5 % (20/364) of degree 4. The meat color was pale in 73.4 % (267/364), pink in 18.1 % (66/364), and red in 8.5 % (31/364). The ADG (± SD) averaged 1.27 ± 0.3 kg. The feeding groups mix ($P < 0.05$), corn pellets ($P < 0.05$), and hay ($P < 0.01$) had a significantly lower ADG as compared to the straw group (Tab. 9). There were no significant differences in ADG among the mix,

Table 9: Performance of 364 slaughtered Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Item	Wheat straw (control) n = 75	Mix[4] n = 73	Corn silage n = 68	Corn pellets n = 75	Hay n = 73
Conformation[1] (No. of calves)					
C	2 (2.7 %)	4 (5.5 %)	–	–	1 (1.4 %)
H	4 (5.3 %)	4 (5.5 %)	3 (4.4 %)	2 (2.7 %)	2 (2.7 %)
T	58 (77.3 %)	48 (65.8 %)	47 (69.1 %)	58 (77.3 %)	43 (58.9 %)
A	11 (14.7 %)	14 (19.2 %)	15 (22.1 %)	13 (17.3 %)	18 (24.7 %)
X	–	3 (4.1 %)	3 (4.4 %)	2 (2.7 %)	9* (12.3 %)
Fat cover[2] (No. of calves)					
1	3 (4 %)	12 (16.4 %)	6 (8.8 %)	10 (13.3 %)	11 (15.1 %)
2	15 (20 %)	18 (24.7 %)	20 (29.4 %)	18 (24 %)	25 (34.2 %)
3	53 (70.7 %)	37 (50.7 %)	37 (54.4 %)	43 57.3 %)	36 (49.3 %)
4	4 (5.3 %)	6 (8.2 %)	5 (7.4 %)	4 (5.3 %)	1 (1.4 %)
Meat color (No. of calves)					
pale	57 (76 %)	51 (69.9 %)	50 (73.5 %)	51 (68 %)	58 (79.5 %)
pink	14 (18.7 %)	13 (17.8 %)	14 (20.6 %)	13 (17.3 %)	12 (16.4 %)
red	4 (5.3 %)	9 (12.3 %)	4 (5.9 %)	11 (14.7 %)	3 (4.1 %)
ADG[3] (kg)	1.35 ± 0.2	1.25* ± 0.3	1.29 ± 0.3	1.27* ± 0.2	1.23* ± 0.3
Mean carcass weight (kg)	126.2 ± 12.3	121.8* ± 13.2	122.9 ± 14.3	119.6* ± 13.2	118.8* ± 15.2
Mean duration of fattening period (days)	112.1 ± 9.2	113.8 ± 13.0	114.1 ± 9.8	114.6 ± 8.5	116.6* ± 9.2
Mean age at slaughter (days)	155.6 ± 13.2	153.4 ± 14.1	156.9 ± 14.0	158.5 ± 13.5	159.8 ± 15.9

* Within rows means are significantly different from straw ($P < 0.05$)
[1] C = very high, H = high, T = medium, A = low, X = very low quality
[2] 1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high fat cover; no significant differences among groups ($P > 0.1$)
[3] Average daily weight gain
[4] Composition: Soy flakes (33 %), corn (10 %), barley (10 %), wheat (10 %), oat (3 %), barley middling (30 %), plant oil (1 %), molasses (3 %)

Table 10: Final multivariable regression model for the effect of feeding treatment, production cycle, initial hemoglobin concentration and initial age on average daily weight gain of 364 Swiss veal calves fed 5 different types of solid feeds in an *ad libitum* feeding system.

Variable	Group comparison	F-ratio	Regression coefficient	95 % confidence interval	P-value
Intercept			1.19	1.03–1.35	< 0.001
Feeding group		3.38			0.010
	Mix vs. straw		−0.10	−0.17–−0.02	0.016
	Corn pellets vs. straw		−0.09	−0.17–−0.01	0.022
	Corn silage vs. straw		−0.05	−0.13–−0.02	0.18
	Hay vs. straw		−0.14	−0.21–−0.06	< 0.001
Production cycle	PC2 (winter) vs. PC1 (summer)	47.24	−0.18	−0.23–−0.13	< 0.001
Initial hemoglobin	Continuous (g/l)	3.86	0.001	0.0001–−0.003	0.05
Initial age	Continuous (days)	11.80	0.003	0.001–0.005	< 0.001

corn pellets, corn silage and hay group ($\alpha = 0.005$). The results of the multivariable regression model for ADG are presented in Table 10. Feed gain ratio averaged 1.93 in the straw group, 2.01 in the mix group, 1.8 in the corn silage group, 1.94 in the corn pellets group, and 2.15 in the hay group.

Discussion

The main objections of Swiss veal producers to providing solid feeds other than straw are a lower ADG, a decline in carcass conformation, darkened meat color, and a decrease in liquid food intake. In the present study, ADG

was highest in the straw group, but no significant effects of feeding treatments on fat cover and meat color were observed. In agreement with previous studies (Gygax et al., 1993; Roth et al. 2009), bovine respiratory disease represented the main health problem in both PCs. Overall, the total number of DDA reported in the present study was higher as compared to other findings in Switzerland (Bähler et al., 2010b). Further analysis of the data revealed that this difference was caused by a higher total of DDA in PC2 during winter. Independently from this study, air quality in the stalls was assessed by the bovine health service. Measurements revealed that the air exchange rate was 300 m^3/h as compared to the recommended 100 m^3/h (van Caenegem, 2006). This excessive air exchange rate in combination with cold temperatures might have lead to chill stress and, thus, to an increased susceptibility to infectious diseases of the respiratory tract.

Lindt and Blum (1994) already noticed that Hb values being considered physiological by various authors show a considerable variation making comparisons difficult. With reference to Bunger et al. (1988) who determined the threshold for anemia to be 105 g/L Hb, all the groups were at least marginally anemic, a status which may also impair immune functions (Sherman, 1992; Gygax et al., 1993). In-depth analysis of data showed that the overall Hb values of the PC1 calves fattened during summer were higher than in the PC2 calves, thus confirming previous reports on seasonal differences (Moser et al., 1994). Reasons for this observation still need to be identified. The Hb concentration of reticulocytes (CHr) was determined, because it is considered to be an indicator of early iron deficiency in humans and dogs (Brugnara et al., 1994; Steinberg and Olver, 2005). Its relevance for veal calves, however, has to be investigated in further studies.

Due to statutory straw bedding for calves, straw intake is possible at any time (Tierschutzgesetz, 2005). This fact might have blurred the disparity in the prevalence of fundic lesions and prevented the difference between the straw group and the other groups from being statistically significant. However, we observed a trend towards a higher prevalence of fundic lesions in calves of the straw group which corroborates earlier findings (van Putten, 1982; Welchman and Baust, 1987; Bähler et al., 2010a).

In terms of performance, carcass weights and ADG were highest in calves of the straw group. This is likely to result from the higher DMI of liquid feed even though statistical evidence for this conclusion is missing. We consider the comparably high ADG of calves of the corn silage group to be an overestimate resulting from a comparatively high proportion of prematurely slaughtered calves as well as fatal losses in this group. However, the ADG observed in this study is relatively high as compared to other countries (Sargeant et al., 1994b; Suarez et al., 2006; Suarez et al., 2007) but rather too low as compared to Swiss expectations (Bähler et al., 2010b).

Reasons for the high proportion of poor carcass conformation associated with hay feeding might be a consequence of the low initial BW combined with the highest proportion of dairy breeds in this group. Regarding meat color, differences among groups were not significant. However, descriptive data indicate that the proportion of red meat was lowest in the hay and straw groups. This finding is consistent with a report by Cozzi et al. (2002) who hypothesized that iron was likely to be trapped in NDF-rich roughage such as hay and wheat straw and, thus, be unavailable for metabolism. Therefore, absolute iron content in these solid feeds may not directly affect meat color.

In summary, wheat straw feeding was associated with a higher prevalence of fundic lesions, a poor development of the ruminal mucosa, the highest percentage of abnormal ruminal content, and a decrease in chewing activity. Despite better growth performance, straw is inappropriate as an exclusive solid feed for veal calves because of its negative impact on their physiological development and welfare. Whole plant corn pellets as a solid supplement to liquid diet complied best with both the calves' physiological requirements and the demands of the market concerning performance. A further advantage of whole plant corn pellets as a solid feed is their convenience: corn pellets are standardized, easy to handle and basically nonperishable. Thus, out of the 5 solid feeds evaluated, we consider whole plant corn pellets to be the additional solid feed of choice for veal calves under Swiss fattening conditions.

Influence des aliments solides sur la santé et la productivité des veaux d'engraissement en Suisse. I: Dérivés du lait comme fourrage de base

Le but de cette étude était de trouver une alternative adéquate à l'affouragement complémentaire de paille chez les veaux d'engraissement. Au cours de 2 périodes d'engraissement avec chaque fois 200 veaux débutant leur engraissement à l'âge de 40 jours, on a étudié l'influence de 5 fourrages grossiers différents sur la santé et la productivité. Les veaux étaient dété-

L'influenza di alimenti solidi sulla salute e le prestazioni dei vitelli da ingrasso svizzeri. I: Sottoprodotti del latte destinati alla produzione di alimenti di base

Lo scopo di questo studio era di trovare una valida alternativa all'attuale alimentazione con paglia per i vitelli da ingrasso. L'influenza di 5 diversi tipi di foraggio grezzo sulla salute e le prestazioni è stata esaminata durante due periodi di ingrasso con 200 vitelli da ingrasso svizzeri ognuno con un'età di inserimento di 40 giorni. I vitelli sono stati tenuti in

nus par groupe de 40 avec un accès libre à un enclos extérieur. Le fourrage liquide se composait d'un sous-produit lacté complété par la poudre de lait et offert ad libitum. On a offert à chaque groupe un des fourrages expérimentaux suivant : mix (composition : flocons de soya, maïs orges, blé, avoine, farine d'orge, huile végétale, mélasse), cubes de mais plante entière, silo de mais, foin et paille de blé pour le groupe de contrôle. La consommation journalière en poids de matière sèche s'élevait en moyenne par veau à 2.25 kg pour l'aliment liquide, 0.16 kg pour la paille, 0.33 kg pour le mix, 0.47 kg pour le silo de mais, 0.38 kg pour les cubes de mais et 0.39 kg pour le foin. Il y avait pas de différence significative entre les groupe quant aux pertes qui atteignaient un total 4.8 % (68 % pour des problèmes gastro-intestinaux). 4 % des veaux ont du être abattu précocement. Les veaux des groupes mix et silo de mais ont été traités plus longtemps avec un antibiotique que le groupe de contrôle paille (groupe mix : 36.9 jours, $P < 0.01$, groupe silo de mais 35 jours, $P < 0.01$). En comparaison avec les 4 autres groupes, les veaux du groupe paille présentaient plus de contenu anormal de la panse (73 %, $P < 0.05$), ils avaient plus fréquemment des villosités de la panse anormales (42 %, $P < 0.05$), plus fréquemment des lésions de la caillette (13.5 %, $P < 0.01$) et ils montraient la moins bonne rumination (45 coups par bolus, $P < 0.05$). La concentration moyenne en hémoglobine était de 85g/l au début et 99 g/l à la fin de l'engraissement sans différence significative entre les groupes ($P > 0.01$). La durée moyenne d'engraissement était de 180 jours, l'âge moyen d'abattage de 157 jours et le poids moyen à l'abattage de 122 kg. La prise de poids moyenne journalière était la plus importante chez les veaux du groupe paille (1.35 Kg) et la plus faible chez les veaux du groupe foin (1.22 kg, $P < 0.01$) Le nombre de carcasses classées bonnes à très bonnes était plus faible dans le groupe foins que dans le groupe paille. Pour ce qui est de la couleur de la viande, on ne pouvait pas constater de différence significative entre les groupes ($P > 0.1$): 73 % des carcasses était classées comme claires (267/364), 18 % comme roses (66/364) und 9 % comme rouges (31/364).
Les présents résultats montrent que les cubes de mais plante entière correspondent le mieux aux besoins en matière de santé et productivité des veaux d'engraissement. Ils peuvent être donc recommandés comme alternative à l'affouragement de paille chez les veaux en Suisse.

gruppi di 40 a stabulazione libera. Il nutrimento liquido era costituito da un sottoprodotto del latte completato da latte in polvere e somministrato ad libitum. A ogni gruppo è stato assegnato uno dei seguenti alimenti sperimentali: mix (composizione: fiocchi di soia, mais, orzo, frumento, avena, farina di orzo, olio vegetale, melassa), cubetti di mais da pianta intera, insilato di mais, fieno e paglia di frumento come gruppo di controllo. La quantità di sostanza secca assimilata in media giornalmente per vitello era di 2.25 kg per l'alimento liquido, 0.16 kg per la paglia, 0.33 per il mix, 0.47 per l'insilato di mais, 0.38 kg per i cubetti di mais e 0.39 per il fieno. Per quanto riguarda le perdite di vitelli, per un totale del 4.8 % (68 % a causa di disturbi intestinali), non sono state rilevate differenze significative tra i due gruppi. Il quattro percento dei vitelli ha dovuto essere macellato precocemente. I vitelli dei gruppi mix e insilato di mais sono stati curati, in rapporto al gruppo di controllo paglia, più a lungo con antibiotici (gruppo mix 36.9 giorni, $P < 0.01$, gruppo di insilato di mais 35 giorni, $P < 0.01$). Rispetto ai 4 altri gruppi, i vitelli del gruppo paglia presentavano più frequentemente un contenuto del rumine anormale (73 %, $P < 0.05$), villi ruminali anormali (42 %, $P < 0.05$), lesioni dell'abomaso nell'area del fondo (13.5 %, $P < 0.1$) e una peggiore ruminazione (45 battiti a bolo, $P < 0.05$). La concentrazione media di emoglobina era di 85 g/l all'inizio e di 99 g/l alla fine dell'ingrasso e non sono state trovate differenze significative tra i gruppi ($P > 0.1$). La durata media dell'ingrasso era di 114 giorni, l'età media di macellazione di 157 giorni e il peso medio della carcassa era di 122 kg. L'aumento di peso medio giornaliero era per i vitelli del gruppo paglia il più alto (1.35 kg) e nei vitelli del gruppo fieno il più basso (1.22 kg, $P < 0.01$). Il numero di carcasse classificate tra buone e molto buone (da T a C) era nel gruppo fieno inferiore rispetto al gruppo paglia ($P < 0.01$). Per quel che riguarda il colore della carne non si sono riscontrate differenze significative tra i gruppi ($P < 0.1$). Il 73 % delle carcasse sono state classificate come chiare (267/364), il 18 % come rosa (66/364) e il 9 % come rosse (31/64). I risultati presentati indicano come i cubetti di mais da pianta intera sono i più adatti per quel che riguarda la salute e le prestazioni dei vitelli da ingrasso. I cubetti di mais da pianta intera possono quindi essere consigliati quali alternativa alla nutrizione con paglia per i vitelli da ingrasso alle condizioni esistenti in Svizzera.

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See part II.

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