Effects of silage additives on intake, gain and carcass traits of growing and finishing dairy bulls

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1.   Introduction

The nutritive value of grass is modified by the fermentation process during ensiling (Thomas and Thomas, 1985). The control of major preservative factors of silage (e.g. pH, water activity, epiphytic flora, anaerobic conditions), and their interactions, is the basis for biologically and economically efficient silage production (Huhtanen *et al.*, 2013). Silage additives are used to improve nutrient recovery, prolong aerobic stability and, in some cases, improve animal performance (Kung and Muck, 1997). In Finland, Virtanen (1933) adopted a method of ensiling, in which rapid acidification and fermentation inhibition was achieved by using mineral salts. Currently 50–60% of the Finnish farm samples analysed in the laboratory of Valio Ltd. are from silages treated with acid based additives, 25–30% from silages treated with biological additives and 10–15% from untreated silages (Huhtanen *et al.*, 2013).

Voluntary feed intake in cattle has a great impact on the performance. Variation in the performance is more closely related to feed intake than to diet digestibility or efficiency of converting digestible energy to metabolisable or net energy (Mertens, 1994). The lower intake of silage than that of corresponding grass or dried hay has often been associated with the fermentation end-products of silage (Huhtanen *et al.*, 2013). A low voluntary feed intake is often found with grass silage based diets because the intake potential of the herbage is reduced as a result of the ensiling process (Cushnahan and Mayne, 1995). Improving fermentation quality of silage has been shown to increase feed intake and performance. In a meta-analysis of data from silage fermentation studies, Huhtanen *et al.* (2003) observed that both the extent and type of in-silo fermentation influenced milk production variables. The yields of milk and milk components decreased with increased concentrations of lactic acid and volatile fatty acids (VFA) in silage (Huhtanen *et al.*, 2003). The silage dry matter intake index (Huhtanen *et al.*, 2007) quantitatively estimates the effects of various silage characteristics on silage intake of dairy cows, and one of the factors significantly affecting silage intake is the extent of fermentation. In finishing steers, Agnew and Carson (2000) observed that steers offered the grass silage with the additive (blend of ammonium hexamethanoate, ammonium hexapropionate and octanoic acid) showed higher daily dry matter (DM) intakes (DMI) and higher daily carcass gains than those offered the silage without additive.

Increasing size of farms and demand for high labour efficiency in the ensiling systems have been the major reasons for the technological development, like pre-wilting and harvesting techniques related to it (Huhtanen *et al.*, 2013). Effluent losses and the risk of clostridial fermentation decreases with increasing silage DM content but at the same time wilting may increase nutrient losses during drying, impair microbiological quality of silage and expose the silage to aerobic deterioration (Huhtanen *et al.*, 2013). In favourable harvesting conditions wilting grass to DM content of 300 g/kg supports achievement of good fermentation quality and feeding value without additives (Heikkilä *et al.*, 2010). Nevertheless, in spite of the low butyric acid and ammonia N content of untreated bale silage having relatively high DM content (380 g DM/kg), the use of inoculants or formic acid base additive improved milk production and sensory quality of milk (Heikkilä *et al.*, 1997) which demonstrates that fermentation parameters of high DM silage insufficiently describe the value of silage in animal production. However, relative to dairy cows, there are few reports available in the literature where the effects of silage additives in growing and finishing bulls offered grass silage with relatively high DM content were examined. Therefore the objective of the present experiment was to study the effects of two silage additives compared with a control without any additive on intake, animal performance and carcass characteristics of growing and finishing dairy bulls. It was hypothesized that the use of

additives would increase the feed intake of the bulls and increasing intake might improve gain and carcass traits.

2.   Materials and methods

2.1.   Animals and housing

A feeding experiment was conducted in the experimental barn of Natural Resources Institute Finland (Luke) in Ruukki, Finland starting in January 2015 and ending in September 2015. Animals were managed according to the Finnish legislation regarding the use of animals in scientific experimentation. The experiment was conducted using in total 45 pure Nordic Red (NR) and 45 pure Holstein (HOL) bulls. All animals, with an initial live weight (LW) of 290 (±24.5) kg, were purchased from commercial herds. At the start of the feeding experiment the animals were on average 251 (±10.0) days old.

During the feeding experiment, the bulls were housed in an uninsulated barn in pens (10.0 × 5.0 m; 5 bulls in each pen), providing 10.0 m^2 per bull. The rear half of the pen area was a straw-bedded lying area and the fore half was a feeding area with a solid concrete floor. A GrowSafe feed intake system (model 4000E; GrowSafe Systems Ltd., Airdrie, AB, Canada; see validation studies: e.g. DeVries *et al.*, 2003; Mendes *et al.*, 2011) was used to record individual daily feed intakes so that each pen contained two GrowSafe feeder nodes. The bulls had free access to water from a water bowl (one bowl per pen) during the experiment.

2.2.   Feeds, feeding and experimental design

Experimental silages were produced at the experimental farm of Luke in Ruukki (64°44'N, 25°15'E) and harvested from timothy (*Phleum pratense*) stands (on June 18 and August 6 2014, primary growth and regrowth, respectively). The stands were cut by mower conditioner (Elho 280 Hydro Balance) and harvested with an integrated round baler wrapper (McHale Fusion 3) approximately 24 hours after cutting.

Three different ensiling treatments were used:
1. Control treatment without additives (CON)
2. Safesil/Salinity Agro (sodium benzoate, potassium sorbate, sodium nitrite), applied at a rate of 5.4 kg/tonne of fresh forage (SAF)
3. AIV ÄSSÄ / Eastman Chemical Company (formic acid, propionic acid, ammonium formate, benzoic acid), applied at a rate of 5.8 kg/tonne of fresh forage (AIV)

At the beginning of the feeding experiment both NR and HOL bulls were randomly allotted to the pens (animals from the same breed were housed together) which were then randomly allotted to three feeding treatments (CON, SAF, AIV; three NR pens and three HOL pens per treatment; 30 bulls per treatment). The diets included experimental silages (600 g/kg DM) and rolled barley grain (400 g/kg DM). The primary growth was fed during the early part of the feeding experiment (135 days) and regrowth during the late part of the experiment (124 days). Thus, the whole feeding experiment lasted 259 days.

The bulls were fed a total mixed ration *ad libitum* (proportionate refusals of 5%). The daily ration included also 150 g of a mineral-vitamin mixture (Kasvuape E-Hiven, A-Rehu Ltd., Seinäjoki, Finland). Two bulls (one SAF and one AIV bull) were excluded from the study due to pneumonia and one bull (SAF) due to several occurrences of bloat. There was no reason to suppose that the diets had caused these problems.

2.3. Feed sampling and analysis

During the feeding experiment silage sub-samples were taken twice a week, pooled over periods of four weeks and stored at –20 ºC prior to analyses. Thawed samples were analysed for DM, ash, crude protein (CP), neutral detergent fibre (NDF) exclusive of residual ash, silage fermentation quality [pH, water-soluble carbohydrates (WSC), lactic and formic acids, ethanol, VFA, soluble and ammonia N content of total N], and digestible organic matter (DOM) in DM (D-value). Barley sub-samples were collected weekly, pooled over periods of 12 weeks and analysed for DM, ash, CP and NDF.

The DM concentration was determined by drying at 105 °C for 20 h and ash concentration by ashing at 600 °C for 2 h. Oven DM concentration of silages was corrected for the loss of volatiles according to Huida *et al.* (1986). After drying the samples were milled using a sample mill (Sakomylly KT-3100, Koneteollisuus Oy, Helsinki, Finland) and 1 mm sieve. Nitrogen content was determined by the Dumas method (AOAC method 968.06; AOAC, 1990) using a Leco FP 428 nitrogen analyzer (Leco, St Joseph, MI, USA). Crude protein content was calculated as 6.25 × N content. Concentration of NDF was determined according to Van Soest *et al.* (1991) using Na-sulphite, without amylase for forages and presented ash-free. The silages were analysed for D-value as described by Huhtanen *et al.* (2006). The pepsin-cellulase solubility values were converted to *in vivo* digestibility using correction equations (different equations for primary growth and regrowth) based on a data set comprising of Finnish *in vivo* digestibility trials (Huhtanen *et al.*, 2006).

Silages were analysed for VFA according to Huhtanen *et al.* (1998), lactic acid according to Haacker *et al.* (1983), WSC according to Somogyi (1945) and ammonia N according to McCullough (1967). Soluble N was measured from water extract using the Kjeldahl method (AOAC method 984.13) with a Foss Kjeltec 2400 Analyzer Unit (Foss Tecator AB, Höganäs, Sweden). Formic acid of the silages was measured using a commercial kit (Cat. No. 979732; Boehringer Mannheim GmbH, Mannheim, Germany). Ethanol content of the silages was measured using an enzymatic kit (Cat. No. 981680; KONE Instruments Corporation, Espoo, Finland) and the selective clinical chemistry analyser Pro 981489 (KONE Instruments) according to application instructions given by KONE.

The metabolisable energy (ME) concentration of the silages was calculated as 0.016 × D-value (MAFF, 1984). The ME concentration of barley was calculated based on concentrations of digestible crude fibre, CP, crude fat and nitrogen-free extract described by Luke (2016). Crude fibre and crude fat concentrations and digestibility coefficients were taken from the Finnish Feed Tables (Luke, 2016). The values of metabolisable protein (MP) and the protein balance in the rumen (PBV) were calculated according to the Finnish feed protein evaluation system (Luke, 2015) in which MP describes the amount of amino acids absorbed from the small intestine and PBV describes the balance between the dietary supply of rumen-degradable protein (RDP) and the microbial requirements for RDP. The relative intake potential of silage DM (SDMI index) was calculated as described by Huhtanen *et al.* (2007).

2.4. Slaughter procedures and carcass quality measurements

The bulls were weighed on two consecutive days at the beginning of the experiment and before slaughter. All the bulls were slaughtered on the same day, and the target for the average carcass weight was 330-335 kg which is the average carcass weight for slaughtered dairy bulls in Finland (Huuskonen, 2014). The LW gain (LWG) was calculated as the difference between the means of the initial and final LW divided by the number of growing days. The estimated rate of carcass gain was calculated as the difference between the final carcass weight and the carcass weight at the beginning of the experiment divided by the number of growing days. The

carcass weight at the start of the experiment was assumed to be 0.50 based on earlier studies (unpublished data).

The animals were slaughtered in the Atria Ltd. commercial slaughterhouse in Kauhajoki, Finland. After slaughter the carcasses were weighed hot. The cold carcass weight was estimated as 0.98 of the hot carcass weight. Dressing proportions were calculated from the ratio of cold carcass weight to final LW. The carcasses were classified for conformation and fatness using the EUROP quality classification (EC, 2006). For conformation, the development of the carcass profile, in particular the essential parts (round, back, shoulder), was taken into consideration according to the EUROP classification (E: excellent, U: very good, R: good, O: fair, P: poor). Each level of the conformation scale was subdivided into three sub-classes to produce a transformed scale ranging from 1 to 15, with 15 being the best conformation. For fat cover degree, the amount of fat on the outside of the carcass and in the thoracic cavity was taken into account using a classification range from 1 to 5 (1: low, 2: slight, 3: average, 4: high, 5: very high).

2.5.   Statistical methods

The results are shown as least squares means. The data were subjected to analysis of variance using the SAS GLM procedure (version 9.4, SAS Institute Inc., Cary, NC, USA). The silage chemical composition and fermentation quality were tested in both primary growth and regrowth using the statistical model

$$y_{ij} = \mu + \alpha_i + e_{ij}$$

where μ is the overall mean, e_{ij} is the random error term and α_i is the effect of treatment.

The statistical model used for feed intake, growth performance and carcass traits was

$$y_{ijkl} = \mu + \alpha_i + \gamma_j + (\alpha \times \gamma)_{ij} + \theta_{ijl} + \beta x_{ijk} + e_{ijkl}$$

where μ is the intercept and e_{ijkl} is the residual error term associated with l^{th} animal. α_i, γ_j and $(\alpha \times \gamma)_{ij}$ are the effects of ith diet (CON, SAF, AIV) and j^{th} breed (NR, HO) and their interaction, respectively, while θ_{ijl} is the effect of pen. The effect of pen was used as an error term when differences between treatments were compared because treatments were allocated to animals penned together. Initial LW was used as a covariate (βx_{ijk}) in the model.

Differences between the ensiling treatments were tested using two contrasts: (1) CON vs. SAF and (2) CON vs. AIV. Breed had only minor and expected differences so the effects of the breeds are not presented in the tables. Since the interactions between the breed and ensiling treatments were not statistically significant (P>0.10 for all variables), the P-values of the interactions are not presented.

3.   Results

3.1.   Chemical composition and feeding values

Chemical composition and fermentation quality of the silages are presented in Tables 1 and 2 (primary growth and regrowth, respectively). The herbages were wilted rapidly so relatively high average DM contents (362 and 389 g/kg for primary growth and regrowth, respectively) were achieved. There were no significant differences in DM contents among the experimental silages. Silage ME content was on average 11.18 and 9.80 MJ/kg DM and CP content 159 and 175 g/kg DM for primary growth and regrowth, respectively. There were no significant differences in the ME or CP contents among the experimental silages (Table 1 and 2). The primary growth of the AIV treatment had 13% lower ash concentration compared to the CON ($P<0.01$) but there was no difference in the ash content between the CON and SAF. Looking at the regrowth, there were no differences in the ash content among the experimental silages. Still, the primary growth of the AIV treatment had 4% higher silage DM intake index compared to the CON ($P<0.01$) but there was no difference in the silage DM intake index between the CON and SAF. Looking at the regrowth, there were no differences in the silage DM intake index among the experimental silages.

3.2.   Fermentation quality

The pH of the primary growth was 4.26, on average, and there were no differences among the ensiling treatments (Table 1). The primary growth of the AIV treatment contained 33% less lactic acid ($P<0.001$), 23% less ethanol ($P<0.01$), 13% less ammonium N ($P<0.01$) and 63% more WSC ($P<0.001$) compared to the CON treatment. The primary growth of the SAF contained 19 % less ethanol ($P<0.05$) and tended to contain 11% less lactic acid ($P=0.07$) and 19% more WSC ($P=0.07$) compared to the CON silage (Table 1).

The major VFA in all silages was acetic acid (Tables 1 and 2). The primary growth of the AIV treatment contained 24% less total VFA ($P<0.01$) and 33% less acetic acid ($P<0.001$) but more than three times more propionic acid ($P<0.001$) compared to the CON silage. The primary growth of the SAF contained 13 % less total VFA ($P<0.05$) and tended to contain 12% less acetic acid ($P=0.06$) compared to the CON. The level of butyric acid was low in all silages but, however, the primary growth of the treated treatments tended to contain less butyric acid compared to the CON (Table 1).

Looking at the regrowth, there were no differences in WSC, total VFA, acetic acid, butyric acid, ammonium N or soluble N contents among the experimental silages (Table 2). However, the pH of the SAF silage was 3% higher ($P=0.01$) and ethanol content 34% lower ($P<0.05$) compared to the CON silage. The regrowth of the AIV treatment contained 32% less lactic acid ($P<0.05$), 32% less ethanol ($P<0.05$) and five times more propionic acid ($P<0.001$) compared to the CON.

7

Table 1. Chemical composition and feeding values of the grass silages used during the early part of the feeding experiment (primary growth of timothy).

Additive	Control	SafeSil	AIV ÄSSÄ	SEM[a]	Contrasts (P-values)[b]	
					1	2
Number of feed samples	5	5	5			
Dry matter (DM), g/kg feed	356	358	371	7.5	0.83	0.18
Ash, g/kg DM	67	64	58	1.7	0.29	0.008
Crude protein, g/kg DM	162	154	161	7.0	0.43	0.90
Neutral detergent fibre, g/kg DM	528	542	535	7.6	0.23	0.51
Metabolisable energy, MJ/kg DM	11.17	11.12	11.24	0.052	0.48	0.37
Metabolisable protein, g/kg DM	88	87	88	1.1	0.31	0.90
Protein balance in the rumen, g/kg DM	31	24	29	5.7	0.44	0.81
Digestible organic matter in DM, g/kg DM	698	695	703	3.3	0.48	0.37
Silage DM intake index	110	110	114	0.6	0.63	0.003
Fermentation quality						
pH	4.24	4.28	4.27	0.024	0.23	0.38
Lactic acid, g/kg DM	55.6	49.3	37.4	2.16	0.07	<0.001
Formic acid, g/kg DM	0.1	0.1	3.6	0.38	0.97	<0.001
Water soluble carbohydrates, g/kg DM	79.4	94.8	129.5	5.22	0.07	<0.001
Ethanol, g/kg DM	8.8	7.1	6.8	0.39	0.02	0.007
Volatile fatty acids, g/kg DM	14.6	12.7	11.1	0.52	0.04	0.002
Acetic acid, g/kg DM	13.5	11.9	9.1	0.54	0.06	<0.001
Propionic acid, g/kg DM	0.41	0.33	1.44	0.110	0.61	<0.001
Butyric acid, g/kg DM	0.35	0.30	0.29	0.019	0.07	0.06
Ammonium-N, g/kg N	54.8	52.4	47.5	1.32	0.23	0.005
Soluble N, g/kg N	449	451	419	19.8	0.93	0.32

[a] SEM = standard error of mean.

[b] Contrasts: 1 = Control vs. SafeSil, 2 = Control vs. AIV ÄSSÄ.

Chemical composition and feeding values of barley used: DM 877 g/kg, crude protein 129 g/kg DM, metabolisable energy 13.2 MJ/kg DM, metabolisable protein 99 g/kg DM, protein balance in the rumen -19 g/kg DM.

Table 2. Chemical composition and feeding values of the grass silages used during the late part of the feeding experiment (regrowth of timothy).

Additive	Control	SafeSil	AIV ÄSSÄ	SEM[a]	Contrasts (P-values)[b]	
					1	2
Number of feed samples	4	4	4			
Dry matter (DM), g/kg feed	390	399	378	20.3	0.77	0.70
Ash, g/kg DM	75	79	74	1.9	0.20	0.85
Crude protein, g/kg DM	177	174	173	8.0	0.86	0.77
Neutral detergent fibre, g/kg DM	564	578	564	4.0	0.06	0.94
Metabolisable energy, MJ/kg DM	9.88	9.66	9.87	0.098	0.16	0.91
Metabolisable protein, g/kg DM	85	84	85	0.6	0.13	0.99
Protein balance in the rumen, g/kg DM	51	51	47	7.6	0.96	0.72
Digestible organic matter in DM, g/kg DM	618	604	617	6.1	0.16	0.91
Silage DM intake index	95	93	97	2.0	0.51	0.56
Fermentation quality						
pH	4.59	4.74	4.52	0.028	0.01	0.11
Lactic acid, g/kg DM	39.8	33.1	27.2	3.47	0.22	0.04
Formic acid, g/kg DM	0.1	0.1	5.4	0.41	0.83	<0.001
Water soluble carbohydrates, g/kg DM	53.5	53.7	73.3	9.70	0.99	0.20
Ethanol, g/kg DM	3.8	2.5	2.6	0.30	0.02	0.03
Volatile fatty acids, g/kg DM	14.5	15.7	10.9	2.60	0.75	0.36
Acetic acid, g/kg DM	13.5	14.7	8.3	2.57	0.74	0.21
Propionic acid, g/kg DM	0.39	0.42	1.92	0.105	0.87	<0.001
Butyric acid, g/kg DM	0.36	0.29	0.34	0.026	0.12	0.75
Ammonium-N, g/kg N	66.2	71.2	56.6	7.79	0.67	0.41
Soluble N, g/kg N	381	349	371	52.2	0.69	0.90

[a] SEM = standard error of mean.

[b] Contrasts: 1 = Control vs. SafeSil, 2 = Control vs. AIV ÄSSÄ.

Chemical composition and feeding values of barley used: DM 888 g/kg, crude protein 115 g/kg DM, metabolisable energy 13.2 MJ/kg DM, metabolisable protein 97 g/kg DM, protein balance in the rumen -31 g/kg DM.

Table 3. Feed and nutrient intake of the bulls fed different total mixed rations.

	Diet[a]			SEM[b]	Contrasts (P-values)[c]	
	Control	SafeSil	Ässä		1	2
Number of observations	30	28	29	-	-	-
Dry matter (DM) intake, kg/d						
Early part, 135 days (primary growth of timothy)	9.51	9.03	8.76	0.136	0.02	<0.001
Late part, 124 days (regrowth of timothy)	10.74	11.38	11.26	0.317	0.15	0.24
Total experimental period, 259 days	9.92	10.14	9.59	0.332	0.62	0.47
DM intake, g/metabolic live weight ($LW^{0.75}$)						
Early part	107	102	100	1.3	0.005	<0.001
Late part	91	98	97	2.6	0.08	0.09
Total experimental period	99	101	97	3.2	0.62	0.62
Nutrient intake						
Early part						
Metabolisable energy, MJ/d	114	108	106	1.6	0.009	<0.001
Crude protein, g/d	1412	1297	1292	19.9	<0.001	<0.001
Metabolisable protein, g/d	883	829	813	12.6	0.003	<0.001
Late part						
Metabolisable energy, MJ/d	121	127	127	3.6	0.24	0.23
Crude protein, g/d	1636	1720	1685	48.1	0.21	0.46
Metabolisable protein, g/d	968	1017	1015	28.5	0.22	0.24
Total experimental period						
Metabolisable energy, MJ/d	115	117	112	3.9	0.77	0.46
Crude protein, g/d	1491	1496	1426	49.6	0.95	0.34
Metabolisable protein, g/d	907	918	877	30.3	0.80	0.46

[a] Diets: Control = timothy silage without additive (600 g/kg DM) + rolled barley (400 g/kg DM), Safesil = timothy silage with Safesil (600 g/kg DM) + rolled barley (400 g/kg DM), Ässä = timothy silage with AIV ÄSSÄ (600 g/kg DM) + rolled barley (400 g/kg DM).
[b] SEM = standard error of mean.
[c] Contrasts: 1 = Control vs. SafeSil, 2 = Control vs. Ässä.

Table 4. Growth performance and feed conversion rate of the bulls fed different total mixed rations.

	Diet[a]			SEM[b]	Contrasts (P-values)[c]	
	Control	SafeSil	Ässä		1	2
Number of observations	30	28	29	-	-	-
Live weight gain, g/d						
Early part (primary growth of timothy)	1601	1490	1524	30.7	0.01	0.07
Late part (regrowth of timothy)	1185	1167	1130	26.4	0.62	0.14
Total experimental period	1408	1340	1341	24.7	0.054	0.054
Carcass gain, g/d	747	736	741	15.6	0.60	0.78
Feed conversion rate						
Early part						
Kg dry matter/kg live weight gain	5.94	6.06	5.75	0.126	0.50	0.16
MJ/kg live weight gain	71.5	72.6	69.2	1.51	0.63	0.17
g CP/kg live weight gain	882	870	848	18.4	0.48	0.09
Late part						
Kg dry matter/kg live weight gain	9.06	9.75	9.96	0.351	0.37	0.17
MJ/kg live weight gain	102.0	108.6	112.2	3.95	0.49	0.16
g CP/kg live weight gain	1381	1474	1491	53.2	0.46	0.30
Total experimental period						
Kg dry matter/kg live weight gain	7.05	7.57	7.15	0.256	0.18	0.87
MJ/kg live weight gain	81.7	87.3	83.5	2.97	0.25	0.87
g CP/kg live weight gain	1059	1116	1063	38.1	0.35	0.95
Kg dry matter/kg carcass gain	13.28	13.78	12.94	0.488	0.57	0.45
MJ/kg carcass gain	153.9	159.0	151.1	5.67	0.70	0.45
g CP/ kg carcass gain	1996	2033	1924	72.8	0.86	0.33

[a] Diets: Control = timothy silage without additive (600 g/kg DM) + rolled barley (400 g/kg DM), Safesil = timothy silage with Safesil (600 g/kg DM) + rolled barley (400 g/kg DM), Ässä = timothy silage with AIV ÄSSÄ (600 g/kg DM) + rolled barley (400 g/kg DM).
[b] SEM = standard error of mean.
[c] Contrasts: 1 = Control vs. SafeSil, 2 = Control vs. Ässä.

Table 5. Live weights and carcass characteristics of the bulls fed different total mixed rations.

	Diet[a]			SEM[b]	Contrasts (P-values)[c]	
	Control	SafeSil	Ässä		1	2
Number of observations	30	28	29	-	-	-
Live weight, kg						
Initial live weight	287	295	290	2.4	0.17	0.57
Middle live weight (after 135 days)	503	496	496	4.6	0.24	0.21
Final live weight	650	641	636	6.7	0.30	0.12
Slaughter age, d	508	511	509	1.7	0.24	0.76
Carcass characteristics						
Carcass weight, kg	336	336	333	4.1	0.91	0.57
Dressing proportion, g/kg	517	524	524	2.9	0.09	0.07
Conformation, EUROP	4.77	5.11	5.00	0.093	0.007	0.05
Fat score, EUROP	2.60	2.43	2.38	0.102	0.21	0.11
Value, €/kg (without a value-added tax)	3.08	3.14	3.15	0.029	0.09	0.08

[a] Diets: Control = timothy silage without additive (600 g/kg DM) + rolled barley (400 g/kg DM), Safesil = timothy silage with Safesil (600 g/kg DM) + rolled barley (400 g/kg DM), Ässä = timothy silage with AIV ÄSSÄ (600 g/kg DM) + rolled barley (400 g/kg DM).
[b] SEM = standard error of mean.
[c] Contrasts: 1 = Control vs. SafeSil, 2 = Control vs. Ässä.

3.3. Feed and nutrient intake

The feeding experiment lasted in total 259 days. During the early (135 days) and late (124 days) part of the feeding experiment the primary growth and regrowth of timothy was used, respectively.

Ensiling treatments affected intake parameters (Table 3). During the early part of the experiment total DM intake of the CON bulls was 5.3 % higher ($P<0.05$) than that of the SAF bulls and 8.6% higher ($P<0.001$) than that of the AIV bulls. Further, DM intake per metabolic LW ($LW^{0.75}$) was 5 and 7% higher in the bulls fed the CON silage compared to the SAF and AIV bulls, respectively. Energy intake was 5.6% ($P<0.01$), CP intake 8.9% ($P<0.001$) and MP intake 6.5 % ($P<0.01$) higher in the CON bulls compared to the SAF bulls. Respectively, ME, CP and MP intakes were 7.5, 9.3 and 8.6% higher in the CON bulls compared to the AIV bulls during the early part of the experiment.

During the late part of the feeding experiment when regrowth silage was fed, there were no treatment differences in total DM intake (on average 11.1 kg DM/d). However, DM intake per metabolic LW tended to be higher in the bulls fed treated silages compared to the CON bulls. There were no treatment differences in ME, CP or MP intakes during the late part of the experiment.

During the total experimental period, the average DM, ME and CP intakes were 9.88 g/kg DM, 115 MJ/d and 1680 g/d, respectively. There were no significant treatment differences among the treatments.

3.4. Growth performance, feed conversion and carcass characteristics

During the early part of the experiment the LWG of the CON bulls was 7.4% higher ($P=0.01$) than that of the SAF bulls and tended to be 5.1% higher ($P=0.07$) than that of the AIV bulls. There were no treatment differences in the LWG during the late part of the experiment (Table 4). During the total experimental period the LWG of the CON bulls tended to be 5.1% higher ($P=0.054$) compared to the bulls fed treated silages. The carcass gain of the bulls was 741 g/d, on average, and there were no differences among treatments. There were no differences in feed, energy or CP conversion rates among the treatments (Table 4).

The slaughter age and final LW of the bulls were on average 509 days and 642 kg, respectively (Table 5). There were no treatment differences in the slaughter age or final LW. The average carcass weight of the bulls was 335 kg and there was no difference among treatments. Dressing proportion of the SAF and AIV bulls tended to be 1.4% higher ($P<0.10$) compared to the CON bulls. Carcass conformation score of the SAF and AIV bulls was 7.1 and 4.8 % higher, respectively, compared to the CON bulls. There were no differences in carcass fat score among the treatments (Table 5). The value of the carcasses (€/kg) consists of the carcass weight, conformation score and possible fat penalties. In the present study, the carcass value of the SAF and AIV bulls tended to be 1.9 and 2.3% higher compared to the CON bulls ($P<0.10$).

4. Discussion

In the present experiment, the CON silages were of relatively good quality which is in line with Heikkilä *et al.* (2010) who concluded that wilting grass to DM content of 300 g/kg supports achievement of good fermentation quality even without additives. Also Seppälä *et al.* (2016) stated that for high DM silages the benefits for using additives were not quite clear. However, despite the wilting, both the SAF and AIV tended to be capable of improving fermentation quality in some respects in the present study. The SAF treatment seemed to affect mostly the

ethanol content of the silages. More positive effects on silage quality parameters with the same SAF treatment were detected by Knicky and Spörndly (2009, 2011). The observations by Knicky and Spörndly (2009) indicated that a mixture of sodium benzoate, potassium sorbate and sodium nitrate efficiently improves silage quality for crops with both high and low DM content.

Formic acid is classified as an inhibitor of fermentation (Kung *et al.*, 2003). Huhtanen *et al.* (2013) concluded that a high application rate of formic acid restricts fermentation resulting in lower content of total acids (lactic acid plus VFA) and ammonia N, and higher content of residual WSC in silage as compared with extensively fermented untreated silage. This is in line with the present experiment, and especially looking at the primary growth. Also Seppälä *et al.* (2016) observed that the total amount of fermentation acids (lactic acid plus VFA) was lower in acid-treated silages compared to untreated silage. However, this was observed only in the low DM (217–230 g DM/kg) and not in the high DM (504–543 g DM/kg) silages (Seppälä *et al.*, 2016). The formic acid based additive used in the present study included also propionic acid, and therefore the AIV silages included more propionic acid compared to the CON silages.

The explanation for the decreasing feed intake of the bulls fed with treated silages during the early part of the feeding experiment is unclear. Although the primary growth of the AIV treatment had higher DM intake index compared to the CON silage, the total DMI of the CON bulls was clearly higher compared to the AIV bulls. Theoretically, the higher propionic acid concentration of the AIV silage could partly explain lower DMI. Huuskonen *et al.* (2013) observed that the concentration of propionic acid in silage had a much stronger influence on silage DMI than other VFAs when modelling factors affecting voluntary feed intake of growing cattle. This is in agreement also with studies in dairy cows (Huhtanen *et al.*, 2002) and growing cattle (Krizsan and Randby, 2007). However, it seems more likely that these earlier results describe the process of secondary fermentation rather than indicating a causal effect of propionic acid on DM intake (Krizsan and Randby, 2007), and also Huhtanen *et al.*, (2002) considered it improbable that the small concentrations of propionic acid found in silage would directly influence intake. In addition, there was no corresponding difference in intake during the late part of the feeding experiment although also the AIV silage from the regrowth had a higher propionic acid concentration compared to the CON silage.

During the total experimental period there were no differences in feed intake between the untreated and treated treatments. This disagrees with findings of O'Kiely and Moloney (1994) and Agnew and Carson (2000). Agnew and Carson (2000) concluded that the additive treatment increased silage DM intake of steers by 21% compared with untreated silage. Distinctions between the present study and those earlier observations can be due to differences in silage DM content. The low DM silages (167–230 g DM/kg) were used in the experiments reported by O'Kiely and Moloney (1994) and Agnew and Carson (2000), and therefore additive treatments clearly improved fermentation quality of the studied silages. Earlier, Parker and Crawshaw (1982), in summarizing 22 experiments, observed a 16% increase in silage DM intake in response to formic acid when silage made without additive preserved badly while there was no benefit from formic acid when the control silage was well fermented.

Higher daily DM intake of the CON bulls during the early part of the experiment compared to the SAF and AIV bulls was reflected also as larger daily ME and nutrient intake. Observed difference in ME intake is probably a crucial explanation for the improved live weigh gain of the CON bulls compared to the bulls fed with the treated silages. Based on the meta-analysis of feeding experiments, Huuskonen and Huhtanen (2015) found that energy intake is clearly the most important variable affecting LWG of growing cattle.

14

In spite of the slightly improved LWG of the CON bulls, there were no differences in the carcass gain among treatments because the dressing proportion of the SAF and AIV bulls tended to be higher compared to the CON bulls. Previous results comparing untreated and treated silages in the diets of growing cattle are slightly conflicting. Agnew and Carson (2000) reported that additive treatment increased LWG and carcass gain when cattle received no concentrate supplementation. However, there was no increase in carcass gain with supplement levels above 1.5 kg/d, even though silage DM intake was increased by the additive at each level of concentrate supplementation. O'Kiely and Moloney (1994) observed that both additives used in the experiment 1 (formic acid and acid-complex) increased silage DM intake and daily LWG. However, in their experiment 2, additives had no significant effects on overall LWG. Distinctions between the present study and earlier observations can be due to, for example, differences in silages DM content, fermentation quality and concentrate feeding strategies used. In some previous experiments the reported values of silage fermentation indicate that those silages were both extensively and poorly fermented in contrast to the present study. In addition, silages were often fed as sole feeds or with clearly lower concentrate allowances compared to the present experiment. The significance of silage fermentation quality is highlighted if it is fed as a sole feed.

Due to the improved carcass conformation score of the SAF and AIV bulls, also the carcass value of these bulls tended to be higher compared to the CON bulls. Also Agnew and Carson (2000) reported that animals offered the additive-treated silage had a higher conformation grade than those offered the untreated silages. However, that observation by Agnew and Carson (2000) was probably due to higher carcass weight of the animals offered the treated silage because, in general, carcass conformation improves with higher carcass weight (Kempster et al., 1988; Keane and Allen, 1998). Contrary to the present experiment, O'Kiely and Moloney (1994) observed no effects of additive treatment on carcass conformation score when animals were slaughtered without differences in carcass weights.

5. Conclusions

Both SAF and AIV were capable of improving silage fermentation quality in some respects in the present study. Contrary to the hypothesis, the use of additives did not increase feed intake of the bulls. There were no differences in carcass gain or feed conversion rates among the treatments. However, due to the improved carcass conformation score of the SAF and AIV bulls, the carcass value of these bulls tended to be higher compared to the CON bulls.

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