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Effects of cultivars and additives on preservation quality and antinutritional factors of crimped ensiled faba bean seeds

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Introduction

One of the goals of the European Union is to achieve protein self-sufficiency. Faba bean is an annual legume whose profile of amino acids is similar to that of soybean, and that could, therefore, substitute soybean in livestock feeding. Due to its rather long growing time and humid weather conditions during autumn, there may be difficulties in harvesting fully ripened seeds under Northern conditions. Thus, crimping and ensiling could provide a more competitive option for feed preservation than drying. Further, utilization of faba beans is limited especially in pig and poultry feeding due to antinutritional factors, such as vicine and convicine, tannins and oligosaccharides. Crimping and ensiling could be a cost-effective option for preserving faba bean seeds and simultaneously degrading their antinutritional factors (Rinne *et al*., 2020).

Materials and Methods

The faba bean seeds used in this experiment were obtained from Boreal Plant Breeding Ltd. (Jokioinen, Finland). The cultivars selected were Kontu, which is characterized by high vicine and convicine (V+C) concentrations and Vire, which was developed through plant breeding to contain lower levels of V+C. Dried beans were moistened for 1 day with tap water to reach a moisture content of ca. 350 g/kg and crimped using a pilot scale crimper (Nipere Ltd., Teuva, Finland). The moist beans were ensiled using 3 additive treatments that included Control (without additive), a combination of hetero- & homofermentative lactic acid bacteria inoculant (LAB; Kofasil Duo, Addcon, Bitterfeld-Wolfen, Germany) at 1 g/t [2×10^5 cfu / g fresh matter] and a formic and propionic acid based additive (FAPA; AIV Ässä Na, Eastman, Oulu, Finland at 5 l/t). Five replicates per treatment were used so that 4 replicates were plastic vacuum bags and 1 replicate was a 5 L capacity cylindrical silo. After 80 days of storage, the samples were analysed for fermentation quality, aerobic stability and antinutritional factors as described by Rinne *et al*. (2020). Statistical analyses were performed using a PROC MIXED statement of SAS 9.4 with variety and additive as fixed effects and replicate as a random effect. Tukey test was used to establish pairwise comparisons of treatment means and treatment effects were further analysed using contrasts.

Table 1 Chemical composition of the two faba bean cultivars before ensiling

Item	Kontu	Vire
Dry matter (DM), g/kg	612	655
Buffering capacity, g lactic acid/100 g	5.3	5.5
In DM, g/kg		
Ash	37	38
Crude protein	326	277
Starch	379	404
Water soluble carbohydrates	44	47
Neutral detergent fibre	123	126
Vicine	5.53	0.63
Convicine	3.23	0.03
Condensed tannins (proanthocyanidins), mg/100 g	366 (7.85; 36/64)[1)]	1620 (10.6; 30/70)

[1)]Presented as follows: Content (degree of polymerization; procyanidins / prodelphinidins).

Table 2 Preservation quality of two varieties of crimped faba bean (Kontu and Vire) ensiled without additive (C) or using a lactic acid bacteria inoculant (LAB) or formic and propionic acid-based additive (FAPA)

Additive	C		LAB		FAPA		SEM[1)]	Statistical significance			
Variety	Kontu	Vire	Kontu	Vire	Kontu	Vire		Variety	C vs LAB	C vs FAPA	LAB vs FAPA
Dry matter (DM), g/kg	630^{b}	656^{a}	632^{b}	661^{a}	636^{b}	662^{a}	3.4	<0.001	0.282	0.068	0.421
Moisture content, g/kg	370^{a}	344^{b}	368^{a}	339^{b}	364^{a}	338^{b}	3.4	<0.001	0.282	0.068	0.421
pH	4.90^{b}	5.11^{a}	4.61^{c}	4.64^{c}	4.56^{c}	4.65^{c}	0.046	0.008	<0.001	<0.001	0.718
Ammonia N, g/kg N	35.8^{a}	29.0^{bc}	34.5^{ab}	25.3^{c}	12.0^{d}	11.3^{d}	1.36	<0.001	0.080	<0.001	<0.001
In DM, g/kg											
Ethanol	9.1^{b}	14.5^{a}	5.4^{d}	7.6^{c}	2.2^{e}	3.0^{e}	0.30	<0.001	<0.001	<0.001	<0.001
Water soluble carbohydrates	1.0^{b}	1.5^{b}	1.1^{b}	0.5^{b}	23.4^{a}	22.9^{a}	1.57	0.860	0.772	<0.001	<0.001
Lactic acid	31.5^{a}	28.1^{ab}	35.9^{a}	35.7^{a}	18.7^{b}	17.4^{b}	2.40	0.412	0.020	<0.001	<0.001
Acetic acid	6.7^{abc}	7.3^{ab}	7.6^{ab}	8.8^{a}	3.1^{c}	4.1^{bc}	0.80	0.160	0.138	<0.001	<0.001
Propionic acid	0.11^{a}	0.04^{a}	0.04^{a}	0.04^{a}	0^{b}	0^{b}	0.020	0.030	0.094	<0.001	<0.001
Butyric acid	0.04^{a}	0.02^{b}	0.01^{b}	0.01^{b}	0.01^{b}	0.01^{b}	0.003	0.002	<0.001	<0.001	0.702
Vicine	0.03^{c}	0.06^{c}	0.07^{c}	0^{c}	2.81^{a}	0.54^{b}	0.035	<0.001	0.826	<0.001	<0.001
Convicine	0.25^{c}	0^{c}	1.16^{b}	0^{c}	2.64^{a}	0.03^{c}	0.075	<0.001	<0.001	<0.001	<0.001
Condensed tannins, mg/100g[2)]	73	736	123	951	139	942	--				
Aerobic stability 2°C, hours[3)]	172	186	196	223	218	227	21.0	0.261	0.089	0.021	0.474

[a,b,c,d,e]Values within a row with different superscripts differ significantly at $P < 0.05$

[1)]SEM, standard error of the mean

[2)]Condensed tannins (proanthocyanidins) were analysed only from a single sample per treatment

[3)]The length of the observation period was 238 h

Results and Discussion

The chemical composition of crimped faba beans is in Table 1. Expectedly, Vire had lower V+C concentration than Kontu, but also lower CP and higher starch and tannin concentrations. After ensiling, Kontu had slightly higher moisture content than Vire (Table 2). Vire had lower ammonia-N concentration in both Control and LAB-treated seeds compared to Kontu but did not differ when treated with FAPA. In contrast, ethanol concentration was higher in Vire than Kontu only with Control and LAB. Both LAB and FAPA additive treatments decreased pH and ethanol concentration compared to Control, although Control could also be regarded as well preserved. The lower concentrations of ammonia, ethanol, lactic acid and acetic acid in FAPA-treated seeds compared to Control and LAB, irrespective of the cultivar studied, suggest a restriction in fermentation. Ensiling was effective in reducing the antinutritional factors, but the restriction of fermentation by FAPA seemed to also protect V+C from degradation which was more pronounced in Kontu compared to Vire. Tannin degradation was not influenced by the additives used (Figure 1).

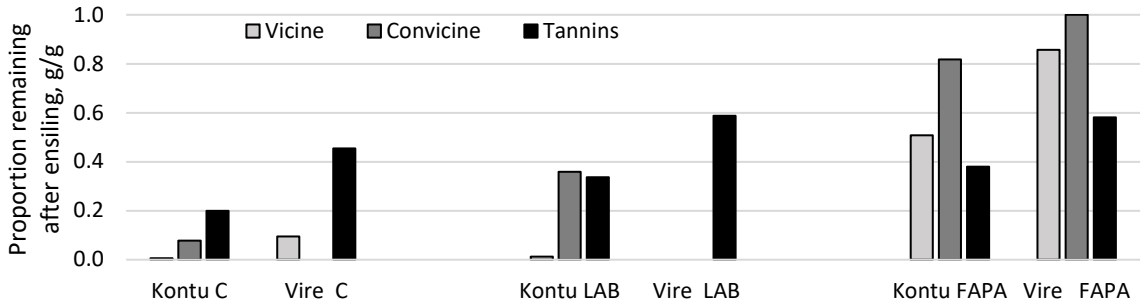

Figure 1 Proportion of antinutritional factors remaining after ensiling two varieties of crimped faba bean (Kontu and Vire) ensiled without additive (C) or using lactic acid bacteria inoculant (LAB) or formic and propionic acid-based additive (FAPA). Vicine: Variety <0.001; C vs LAB = 0.364; C vs FAPA <0.001; LAB vs FAPA <0.001; SEM = 0.043; Convicine: Variety <0.001; C vs LAB <0.001; C vs FAPA <0.001; LAB vs FAPA <0.001; SEM = 0.026.

Conclusions

Crimping and ensiling moist faba beans offers a practical alternative to drying seeds and preservation quality was further improved by using LAB and FAPA additives. The Vire cultivar contained markedly lower V+C concentrations than Kontu, and they were effectively degraded in both cultivars during fermentation except when FAPA was used as an additive, probably due to restriction of fermentation. Tannin concentration in Vire was higher and seemed to be more resistant to degradation than in Kontu, but degradation was unaffected by additives used.

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