The Nutritional Value of Yellow Lupine (*Lupinus luteus*) for Growing Pigs

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**Abstract:** The aim of the study was a comparison of the composition and apparent total tract digestibility (ATTD) of nutrients in the seeds of two varieties of yellow lupine (YL). Moreover, an examination of the level of soybean meal (SBM) substitution by YL meal and in a combination with rapeseed meal (RSM) on the pigs’ performance was performed. In a digestibility trial, 30 male pigs were tested using a marker method. In two growth experiments, 60 pigs (in each) were fed diets where SBM was replaced by YL in 0%, 20%, 40%, 60%, 80% and 100% or by a mixture of RSM and YL or by both these components. The chemical composition of varieties differed among crude protein (CP), fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF) and fat. The digestibility coefficients of protein, fat and gross energy were similar for both varieties. The substitution of SBM with YL did not negatively affect the pigs’ performance. A mixture of RSM with YL had no negative effect on growth parameters, except for the starter phase, when a level of above 15% RSM in the diet reduced the pigs’ gains. In conclusion, YL alone and with RSM may be a sustainable alternative to SBM in pig nutrition.

**Key words:** Alternative protein source, chemical composition, digestibility, growth, pig, yellow lupine.

**1. Introduction**

In recent decades, the usage of soybean meal (SBM) as a main component of feedstuff has become a type of foundation in animal nutrition. As an unmatched source of protein, SBM is difficult to replace. However, under certain circumstances, for instance public pressure regarding the utilization of non-genetically modified organisms (non-GMO) components in animal feedstuff or searching for less expensive, native substitutes of SBM, there is an obligation to use a new vegetable protein.

A promising solution may be the usage of legume seeds—in the past it has almost been excluded from animal nutrition in relation to its high anti-nutritional factors. The progress in plant breeding allowed for a reduction of the alkaloid content in seeds. From cultivated lupine species, yellow lupine (YL) (*Lupinus luteus* L.) stands out from other species with a higher protein content similar to SBM, but despite numerous nutritional benefits it is less often cultivated due to the greater susceptibility to anthracnose [1-3]; In comparison with narrow-leafed lupine, YL also contains lower amounts of crude fiber (CF) but a higher level of oligosaccharides and phytate [3, 4]. Nevertheless, as reported by Martinez-Villaluenga *et al.* [5] and Kasprowicz-Potocka *et al.* [6] nutritional substance content in lupines and plant condition depends on their variety and cultivating conditions. Therefore, the values among varieties may differ significantly. Some researchers have found that Australian YL seeds could be included up to 15% in weaner diets and up to 30% in the diet of Grower and Finisher pigs without compromising pig performance [7]. This is not fully recognized for new lupine varieties in Europe, especially in the context of replacing SBM in pigs’ diets. The replacement of up to 100% of SBM in diets with narrow-leafed lupine seeds (var. Sonet) did not have a negative effect on the fattener performance but negatively affected the
weaner results [8]. Lupine seeds are a poor source of sulphur amino acids, so it is optimistic to use these seeds in combination with rapeseed meal (RSM), which is the main by-product of the oilseed rape processing and is rich in methionine and cystine. On the other side, rapeseed can contain glucosinolates that could negatively impact the animals’ results, but in the Polish species these substances were reduced below 15 μmol/g. Despite this, the substitution of SBM by a combination of narrow-leafed lupine and RSM significantly reduced the performance of growing and finishing pigs [8]. In the study hypothesized that because of the higher protein and energy content and better digestibility of the nutrients, YL seeds and also seeds in combination with RSM can be used as a total replacement of SBM in all pig groups.

The aim of the present investigation was: (1) a comparison of the nutrient composition and apparent total tract digestibility (ATTD) of nutrients in the seeds of two new varieties of YL; (2) an examination of the level of SBM substitution by YL seeds in diets for pigs without compromising growth; (3) replacing SBM in diets of growing and finishing pigs with a combination of YL seeds and RSM.

2. Materials and Methods

2.1 Lupine Seeds

Two cultivars of YL seeds (L. luteus L.) were harvested in 2012: Lord and Mister, registered 2006 and 2003, respectively. Seeds were obtained from the plant breeding stations in Przebedowo and Wiatrowo (both Poland).

2.2 Animals and Diets

All experimental procedures used in this study were in accordance with the guidelines of Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes, but there was no necessity to provide ethical approval. Pigs received the necessary veterinary vaccinations and had unlimited access to water and feed.

2.3 Experiment I

The digestibility experiment was conducted on 30 male pigs of about 25 kg body mass (BM) (Naima × Pietrain × Duroc). Before starting the experiment, animals were housed on straw, which was withdrawn before starting the experiment. The pigs were randomly assigned to three dietary treatments (10 replications in each) and kept in individual cages.

The crude protein (CP) content in the basal diet was approx. 183 g/kg and calculated metabolisable energy (ME) approx. 12.6 MJ/kg of diet. The control pigs were fed the basal diet (Table 1). For the remaining two treatments, the basal diet was mixed at a ratio of 75:25 (w/w) with the different ground lupine seeds (var. Lord and Mister, respectively). The chemical composition of all diets was analyzed (Table 2).

Table 1 Basal diet composition.

| Components                  | %   |
|-----------------------------|-----|
| Wheat meal                  | 47.87 |
| Corn meal                   | 26.00 |
| Soybean meal (SBM)          | 23.00 |
| Monocalcium phosphate       | 1.0  |
| Limestone                   | 1.5  |
| NaCl                        | 0.3  |
| Mineral premixa             | 0.3  |
| Vitamin premixa             | 0.03 |
| Nutritional value           |     |
| Crude protein (CP) (g/kg)   | 183  |
| Lysine (g/kg)               | 9.3  |
| Methionine (g/kg)           | 3.0  |
| Threonine (g/kg)            | 6.4  |
| Tryptophan (g/kg)           | 2.1  |
| Ca (g/kg)                   | 8.4  |
| P (g/kg)                    | 6.3  |
| Calculated metabolisable energy (ME) (MJ/kg) | 12.6 |

Provided per kg diet: Ca, 0.705 g; Fe, 180 mg; Cu, 30 mg; Co, 1.2 mg; Mn, 120 mg; Zn, 180 mg; I, 2.4 mg; Se, 0.6 mg.

Provided per kg diet: Ca, 0.017 g; vitamin A, 15,000 IU; vitamin D3, 1,500 IU; vitamin E, 45 mg; vitamin K3, 1.5 mg; vitamin B1, 2.25 mg; vitamin B2, 4.5 mg; nicotinic acid, 22.5 mg; vitamin B6, 3.0 mg; pantothenic acid, 1.08 mg; vitamin B12, 30 μg; biotin, 75 μg; vitamin C, 60 mg; folic acid, 0.45 mg; antioxidant, 1.5 mg.
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Table 2  Chemical composition of diets (g/kg)—Experiment I.

| Diets                        | Dry matter (DM) | Crude ash (CA) | CP   | Crude fiber (CF) | Ca  | P   |
|-------------------------------|-----------------|----------------|------|------------------|-----|-----|
| Basic                         | 888.4           | 54.60          | 190.0| 26.80            | 10.6| 4.90|
| 75% Basic + 25% seeds var. Lord| 888.7           | 52.80          | 241.9| 57.80            | 8.10| 6.00|
| 75% Basic + 25% seeds var. Mister | 886.7          | 52.20          | 232.8| 57.80            | 7.50| 5.60|

To allow the digestibility to be determined, 3 g/kg titanium dioxide was included as a non-absorbable marker. Fresh water and feed were provided ad libitum throughout the experiment. The experimental diets were fed for a 4-day adaptation period and 3 d of excreta collection. Excreta was individually collected twice per day and immediately frozen and lyophilized before analysis (n = 10). The digestibility coefficients of the component in the test feedstuffs were calculated according to Adeola [9]. The coefficients of ATTD of the components in the test feedstuffs were calculated:

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\text{ATTD} (%) = 100 \times \left( \frac{T \times Tp}{B \times Bp} \right) - \frac{A p}{A p} \]  \( (1) \)

where: ATTD is the digestibility coefficient of the component in the test feedstuff, %; \(T\) is the digestibility of the component in the total diet (basal diet plus the test feedstuff), %; \(B\) is the digestibility of the component in the basal diet, %; \(Bp\) is the proportion of the component in the total diet contributed by the basal diet, %; \(Ap\) is the proportion of the component in the total diet contributed by the test feedstuff, %; \(Tp = Bp + Ap = 100\%\).

2.4 Experiment II

The experiment was conducted on 60 pigs (Naima × (Pi × Du)) of approx. 16.5 kg BM. The pigs were allocated by body weight (BW) and sex (5♀ and 5♂) to six dietary treatments (10 replications each) and kept in individual cages. All of the diets were offered in mash form. The animals from the control group were offered feed with SBM as the sole protein component in the diet (100%), whereas in Group I, 100% of SBM was replaced in a proportion of 75:25 (w/w) with RSM and YL (var. Mister); in Group II, a proportion of 50:50 (w/w) was replaced with RSM and lupine seeds; in Group III a proportion of 25:75 (w/w) was replaced with RSM and lupine seed; in Group IV 100% of SBM was replaced by lupine seeds; in Group V 100% of SBM was replaced by RSM. The experiment lasted 105 d and was divided into three periods—Starter for 37 d, Grower for 34 d and Finisher for 34 d (Tables 3-5). At approximately 105 kg, the pigs were transported to a commercial abattoir for slaughter. Body weight gain (BWG) and feed intake (FI) were recorded, and from this, the average feed conversion ratio (FCR) was calculated.

2.5 Experiment III

The experiment was conducted on 60 pigs (Naima × (Pi × Du)) approx. 26 kg BM. The pigs were allocated by BM and sex (5♀ and 5♂) to six dietary treatments (10 replications each) and kept in individual cages. All of the diets were offered in mash form. The animals from the control group were offered feed with SBM as the sole protein component in the diet (100%), whereas in Group I, 100% of SBM was replaced in a proportion of 75:25 (w/w) with RSM and YL (var. Mister); in Group II, a proportion of 50:50 (w/w) was replaced with RSM and lupine seeds; in Group III a proportion of 25:75 (w/w) was replaced with RSM and lupine seed; in Group IV 100% of SBM was replaced by lupine seeds; in Group V 100% of SBM was replaced by RSM. The experiment lasted 83 d and was divided into three periods—Starter for 21 d, Grower for 35 d and Finisher for 29 d (Tables 6-8). The experiment was finished when animals recorded 105 kg of BM. BWG and FI were recorded and FCR was calculated.

2.6 Chemical Analysis

For chemical analysis, representative samples of seeds were ground to pass through a 0.5 mm sieve. Seeds were analyzed (n = 4) for dry matter (DM), crude ash (CA), CP, ether extract (EE), CF, acid
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Table 3  The composition and nutritional value of diets Starter—Experiment II.

| Components (%) | Control a | L20 b | L40 c | L60 d | L80 e | L100 f |
|----------------|-----------|-------|-------|-------|-------|--------|
| SBM (46%)      | 24.00     | 19.20 | 14.40 | 9.60  | 4.80  | -      |
| Yellow lupin (YL) meal | - | 6.00  | 12.00 | 17.50 | 23.00 | 29.00 |
| Triticale      | 72.5      | 71.26 | 69.99 | 69.27 | 68.5  | 67.24  |
| Calcium phosphate | 1.20   | 1.20  | 1.20  | 1.20  | 1.20  | 1.20   |
| Limestone      | 1.30      | 1.30  | 1.30  | 1.30  | 1.30  | 1.30   |
| NaCl           | 0.35      | 0.35  | 0.35  | 0.35  | 0.35  | 0.35   |
| Premix Starter\(^{\text{g}}\) (0.5%) | 0.50 | 0.50  | 0.50  | 0.50  | 0.50  | 0.50   |
| L-lysine (98.5%) | 0.15     | 0.16  | 0.20  | 0.17  | 0.20  | 0.22   |
| DL-methionine (99%) | 0.00     | 0.00  | 0.02  | 0.04  | 0.07  | 0.08   |
| L-tryptofane (95%) | 0.00   | 0.00  | 0.01  | 0.02  | 0.02  | 0.04   |
| Threonine      | 0.00      | 0.03  | 0.03  | 0.05  | 0.06  | 0.07   |

Nutritional value (g/kg)

| ME (MJ/kg) | 13.0 | 12.9 | 13.0 | 12.9 | 12.9 | 12.9 |
| CP          | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 |
| Ca          | 9.35  | 9.13  | 9.23  | 9.35  | 9.23  | 9.29  |
| P           | 6.25  | 6.53  | 6.53  | 6.59  | 6.40  | 6.77  |

\(^{a}\) Control—groups were offered feed with SBM as the sole protein component in the diet; \(^{b}\) 20% (L20), \(^{c}\) 40% (L40), \(^{d}\) 60% (L60), \(^{e}\) 80% (L80) and \(^{f}\) 100% (L100) of SBM was replaced by YL meal (var. Mister); \(^{g}\) Provided per kg diet: Fe, 100 mg; Cu, 160 mg; Co, 0.4 mg; Mn, 40 mg; Zn, 140 mg; I, 0.8 mg; Se, 0.2 mg; vitamin A, 12,000 IU; vitamin D3, 1,500 IU; vitamin E, 70 mg; vitamin K3, 1.5 mg; vitamin B1, 1.5 mg; vitamin B2, 4.0 mg; vitamin B6, 3.0 mg; vitamin B12, 25 µg; choline chloride, 400 mg; pantothenic acid, 10 mg; nicotinic acid, 20 mg; folic acid, 2.0 mg; biotin, 100 µg; Ca, 0.9 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).

Table 4  The composition and nutritional value of diets Grower—Experiment II.

| Components (%) | Control\(^{a}\) | L20\(^{b}\) | L40\(^{c}\) | L60\(^{d}\) | L80\(^{e}\) | L100\(^{f}\) |
|----------------|---------------|-----------|-----------|-----------|-----------|-----------|
| SBM (46%)      | 22.00         | 17.60     | 13.20     | 8.80      | 4.40      | -         |
| YL meal        | -             | 5.50      | 11.00     | 16.00     | 21.50     | 27.00     |
| Triticale      | 74.82         | 73.77     | 72.46     | 71.81     | 70.65     | 69.50     |
| Calcium phosphate | 0.90    | 0.95      | 0.95      | 0.94      | 0.85      | 0.85      |
| Limestone      | 1.30          | 1.20      | 1.30      | 1.30      | 1.40      | 1.40      |
| NaCl           | 0.29          | 0.29      | 0.30      | 0.30      | 0.30      | 0.30      |
| Premix Grower\(^{g}\) (0.5%) | 0.50 | 0.50  | 0.50  | 0.50  | 0.50  | 0.50  |
| L-lysine (98.5%) | 0.13     | 0.15      | 0.16      | 0.18      | 0.20      | 0.21      |
| DL-methionine (99%) | 0.00     | 0.02      | 0.03      | 0.05      | 0.08      | 0.09      |
| L-tryptofane (95%) | 0.01   | 0.01      | 0.03      | 0.04      | 0.04      | 0.06      |
| Threonine      | 0.02          | 0.01      | 0.07      | 0.08      | 0.08      | 0.08      |

Nutritional value (g/kg)

| ME (MJ/kg) | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 |
| CP          | 181.0 | 180.0 | 180.0 | 181.1 | 180.0 | 180.0 |
| Ca          | 8.76  | 8.56  | 8.73  | 7.72  | 8.64  | 8.65  |
| P           | 6.00  | 6.29  | 6.18  | 6.10  | 6.14  | 6.07  |

\(^{a}\) Control—groups were offered feed with SBM as the sole protein component in the diet; \(^{b}\) 20% (L20), \(^{c}\) 40% (L40), \(^{d}\) 60% (L60), \(^{e}\) 80% (L80) and \(^{f}\) 100% (L100) of SBM was replaced by YL meal (var. Mister); \(^{g}\) Provided per kg diet: Fe, 75 mg; Cu, 20 mg; Co, 0.3 mg; Mn, 30 mg; Zn, 75 mg; I, 0.8 mg; Se, 0.2 mg; vitamin A, 7,500 IU; vitamin D3, 1,500 IU; vitamin E, 52.5 mg; vitamin K3, 1.1 mg; vitamin B1, 1.1 mg; vitamin B2, 3.0 mg; vitamin B6, 2.25 mg; choline chloride, 200 mg; pantothenic acid, 7.5 mg; nicotinic acid, 15 mg; folic acid, 1.5 mg; vitamin B12, 18.5 µg; biotin, 75 µg; Ca, 1.3 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).
Table 5  The composition and nutritional value of diets Finisher—Experiment II.

| Components (%) | Control a | L20 b | L40 c | L60 d | L80 e | L100 f |
|----------------|-----------|-------|-------|-------|-------|--------|
| SBM (46%)      | 15.00     | 12.00 | 9.00  | 6.00  | 3.00  | -      |
| YL meal        | -         | 4.00  | 8.00  | 11.50 | 15.00 | 19.00  |
| Triticale      | 82.38     | 81.39 | 80.37 | 79.80 | 79.28 | 78.25  |
| Calcium phosphate | 0.32       | 0.31  | 0.30  | 0.29  | 0.28  | 0.27   |
| Limestone      | 1.40      | 1.40  | 1.40  | 1.40  | 1.40  | 1.40   |
| NaCl           | 0.22      | 0.24  | 0.23  | 0.24  | 0.23  | 0.24   |
| Premix Finisher d (0.5%) | 0.50      | 0.50  | 0.50  | 0.50  | 0.50  | 0.50   |
| L-lysine (98.5%) | 0.14     | 0.13  | 0.17  | 0.17  | 0.17  | 0.18   |
| DL-methionine (99%) | 0.00    | 0.00  | 0.00  | 0.03  | 0.05  | 0.06   |
| L-tryptofane (95%) | 0.02     | 0.02  | 0.03  | 0.03  | 0.04  | 0.05   |
| Threonine      | 0.02      | 0.02  | 0.03  | 0.04  | 0.05  | 0.05   |

Nutritional value (g/kg)

| ME (MJ/kg) | 13.4 | 13.4 | 13.5 | 13.5 | 13.5 | 13.4 |
| CP          | 161.0| 161.0| 160.0| 160.0| 160.0| 160.0|
| Ca          | 7.81 | 7.69 | 7.78 | 7.74 | 7.72 | 7.75 |
| P           | 4.32 | 4.96 | 4.58 | 4.48 | 4.41 | 5.27 |

a Control—groups were offered feed with SBM as the sole protein component in the diet; b 20% (L20), c 40% (L40), d 60% (L60), e 80% (L80) and f 100% (L100) of SBM was replaced by YL meal (var. Mister); g Provided per kg diet: Fe, 50 mg; Cu, 20 mg; Co, 0.2 mg; Mn, 20 mg; Zn, 40 mg; I, 0.4 mg; Se, 0.1 mg; vitamin A, 5,000 IU; vitamin D3, 1,000 IU; vitamin E, 35 mg; vitamin K3, 0.75 mg; vitamin B1, 1.1 mg; vitamin B2, 2.0 mg; vitamin B6, 1.5 mg; choline chloride, 100 mg; pantothenic acid, 5 mg; nicotinic acid, 10 mg; folic acid, 1.0 mg; vitamin B12, 12.5 μg; biotin, 50 μg; Ca, 1.4 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).

Table 6  Composition and nutrient concentration of the Starter diets in the Experiment III.

| Components (%) | Control a | I b | II c | III d | IV e | V f |
|----------------|-----------|-----|------|-------|------|------|
| SBM (46%)      | 22.00     | -   | -    | -     | -    | -    |
| YL meal        | -         | 7.5 | 15   | 22    | 28.5 | -    |
| Rapseseed meal (RSM) | -         | 23  | 15   | 7.5   | -    | 31.5 |
| Triticale      | 74.64     | 64.11| 64.39| 65.68 | 67.02| 62.73|
| Soya oil       | -         | 2.5 | 2.5  | 1.5   | 1    | 3    |
| Calcium phosphate | 1         | 0.5 | 0.7  | 0.9   | 1    | 0.4  |
| Limestone      | 1.4       | 1.4 | 1.4  | 1.4   | 1.4  | 1.4  |
| NaCl           | 0.34      | 0.34| 0.35 | 0.35  | 0.36 | 0.34 |
| Premix Starter d (0.5%) | 0.5       | 0.5 | 0.5  | 0.5   | 0.5  | 0.5  |
| L-lysine (98.5%) | 0.1       | 0.15| 0.16 | 0.17  | 0.2  | 0.13 |
| DL-methionine (99%) | 0.02     | -   | -    | -     | -    | -    |
| Threonine      | -         | -   | -    | -     | 0.02 | -    |

Nutritional value (g/kg)

| ME (MJ/kg) | 13.0 | 12.9 | 13.0 | 12.9 | 12.9 | 12.9 |
| CP          | 180  | 180  | 180  | 180  | 180  | 180  |
| Ca          | 9.35 | 9.13 | 9.23 | 9.35 | 9.23 | 9.29 |
| P           | 6.25 | 6.53 | 6.53 | 6.59 | 6.4  | 6.77 |

a Control—groups were offered feed with SBM as the sole protein component in the diet; b I-100% of SBM was replaced in a proportion of 75:25 (w/w) with RSM and YL; c II-100% of SBM was replaced in a proportion of 50:50 (w/w) with RSM and YL; d III-100% of SBM was replaced in a proportion of 25:75 (w/w) with RSM and YL; e IV-100% of SBM was replaced by YL; f V-100% of SBM was replaced by RSM; g Provided per kg diet: Fe, 100 mg; Cu, 160 mg; Co, 0.4 mg; Mn, 40 mg; Zn, 140 mg; I, 0.8 mg; Se, 0.2 mg; vitamin A, 12,000 IU; vitamin D3, 1,500 IU; vitamin E, 70 mg; vitamin K3, 1.5 mg; vitamin B1, 1.5 mg; vitamin B2, 4.0 mg; vitamin B6, 5.0 mg; vitamin B12, 25 μg; choline chloride, 400 mg; pantothenic acid, 10 mg; nicotinic acid, 20 mg; folic acid, 2.0 mg; biotin, 100 μg; Ca, 0.9 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).
Table 7  Composition and nutrient concentration of the Grower diets in the Experiment III.

| Components (%)  | Control a | I b  | II c  | III d  | IV e  | V f  |
|-----------------|-----------|------|-------|--------|-------|------|
| SBM (46%)       | 22.50     | -    | -     | -      | -     | -    |
| YL meal         | -         | 7.5  | 15.3  | 22.5   | 29    | -    |
| RSM             | -         | 23.5 | 15.3  | 7.5    | -     | 32   |
| Triticale       | 73.35     | 61.84| 63.01 | 63.91  | 65.2  | 61.07|
| Soya oil        | 1         | 4    | 3.5   | 3      | 2.5   | 4.5  |
| Calcium phosphate| 0.9    | 0.4  | 0.55  | 0.7    | 0.9   | 0.1  |
| Limestone       | 1.3       | 1.3  | 1.35  | 1.35   | 1.3   | 1.4  |
| NaCl            | 0.29      | 0.29 | 0.3   | 0.3    | 0.31  | 0.29 |
| Premix Grower g | 0.5      | 0.5  | 0.5   | 0.5    | 0.5   | 0.5  |
| L-lysine (98.5%)| 0.12      | 0.17 | 0.19  | 0.21   | 0.22  | 0.14 |
| DL-methionine (99%)| 0.04 | -   | -     | -      | 0.02  | -    |
| Threonine       | -         | -    | -     | 0.03   | 0.05  | -    |
| Nutritional value (g/kg) |       |      |       |        |       |      |
| ME (MJ/kg)      | 13.3      | 13.3 | 13.3  | 13.3   | 13.3  | 13.3 |
| CP              | 181       | 180  | 180   | 181    | 180   | 180  |
| Ca              | 8.76      | 8.56 | 8.73  | 8.72   | 8.64  | 8.65 |
| P               | 6.00      | 6.29 | 6.18  | 6.10   | 6.14  | 6.07 |

a Control—groups were offered feed with SBM as the sole protein component in the diet; b I-100% of SBM was replaced in a proportion of 75:25 (w/w) with RSM and YL; c II-100% of SBM was replaced in a proportion of 50:50 (w/w) with RSM and YL; d III-100% of SBM was replaced in a proportion of 25:75 (w/w) with RSM and YL; e IV-100% of SBM was replaced by YL; f V-100% of SBM was replaced by RSM; g Provided per kg diet: Fe, 75 mg; Cu, 20 mg; Co, 0.3 mg; Mn, 30 mg; Zn, 75 mg; I, 0.6 mg; Se, 0.15 mg; vitamin A, 7,500 IU; vitamin D3, 1,500 IU; vitamin E, 52.5 mg; vitamin K3, 1.1 mg; vitamin B1, 1.1 mg; vitamin B2, 3.0 mg; vitamin B6, 2.25 mg; choline chloride, 200 mg; pantothenic acid, 7.5 mg; nicotinic acid, 15 mg; folic acid, 1.5 mg; vitamin B12, 18.5 µg; biotin, 75 µg; Ca, 1.3 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).

Table 8  Composition and nutrient concentration of the Finisher diets in the semi-practical experiment.

| Components (%)  | Control a | I b  | II c  | III d  | IV e  | V f  |
|-----------------|-----------|------|-------|--------|-------|------|
| SBM (46%)       | 17.00     | -    | -     | -      | -     | -    |
| YL meal         | -         | 6    | 11.5  | 17     | 22    | -    |
| RSM             | -         | 18   | 11.5  | 5.5    | -     | 24   |
| Triticale       | 79.49     | 70.26| 71.13 | 72.01  | 72.89 | 69.81|
| Soya oil        | 1         | 3.5  | 3.5   | 3      | 2.5   | 4    |
| Calcium phosphate| 0.2     | -    | -     | 0.1    | 0.2   | -    |
| Limestone       | 1.5       | 1.4  | 1.5   | 1.5    | 1.5   | 1.35 |
| NaCl            | 0.25      | 0.24 | 0.25  | 0.25   | 0.26  | 0.24 |
| Premix Finisher g | 0.5   | 0.5  | 0.5   | 0.5    | 0.5   | 0.5  |
| L-lysine (98.5%)| 0.06      | 0.1  | 0.12  | 0.14   | 0.15  | 0.1  |
| Nutritional value (g/kg) |       |      |       |        |       |      |
| ME (MJ/kg)      | 13.4      | 13.4 | 13.5  | 13.5   | 13.5  | 13.4 |
| CP              | 161       | 161  | 160   | 160    | 160   | 160  |
| Ca              | 7.81      | 7.69 | 7.78  | 7.74   | 7.72  | 7.75 |
| P               | 4.32      | 4.96 | 4.58  | 4.48   | 4.41  | 5.27 |

a Control—groups were offered feed with SBM as the sole protein component in the diet; b I-100% of SBM was replaced in a proportion of 75:25 (w/w) with RSM and YL; c II-100% of SBM was replaced in a proportion of 50:50 (w/w) with RSM and YL; d III-100% of SBM was replaced in a proportion of 25:75 (w/w) with RSM and YL; e IV-100% of SBM was replaced by YL; f V-100% of SBM was replaced by RSM; g Provided per kg diet: Fe, 50 mg; Cu, 20 mg; Co, 0.2 mg; Mn, 20 mg; Zn, 40 mg; I, 0.4 mg; Se, 0.1 mg; vitamin A, 5,000 IU; vitamin D3, 1,000 IU; vitamin E, 35 mg; vitamin K3, 0.75 mg; vitamin B1, 1.1 mg; vitamin B2, 2.0 mg; vitamin B6, 1.5 mg; choline chloride, 100 mg; pantothenic acid, 5.0 mg; nicotinic acid, 10 mg; folic acid, 1.0 mg; vitamin B12, 12.5 µg; biotin, 50 µg; Ca, 1.4 g; antioxidants (butylated hydroxyanisole, butylated hydroxytoluene).
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The chemical composition of legume seeds could vary significantly because of the variety and environmental conditions. The seeds of L. luteus var.
Table 9  Chemical composition of YL seeds in DM.

| Composition                      | Lord  | Mister | Mean   | SD    |
|---------------------------------|-------|--------|--------|-------|
| CA (g/kg)                       | 42.73 | 41.53  | 42.13  | 0.41  |
| CP (g/kg)                       | 443.75| 389.84 | 416.85 | 30.21 |
| CF (g/kg)                       | 209.12| 192.34 | 200.73 | 0.51  |
| Acid detergent fiber (ADF) (g/kg)| 201.14| 242.42 | 221.83 | 10.82 |
| Neutral detergent fiber (NDF) (g/kg)| 238.22| 282.42 | 260.32 | 14.65 |
| Ether extract (EE) (g/kg)       | 44.72 | 52.61  | 48.71  | 2.11  |
| N-free extractives (NFE) (g/kg) | 259.96| 323.82 | 291.94 | 7.64  |
| Lysine (g/100 g of protein)     | 4.55  | 4.76   | 4.66   | 0.11  |
| Methionine + cystine (g/100 g of protein) | 2.89 | 3.37 | 3.13 | 0.09 |
| Threonine (g/100 g of protein)  | 3.29  | 3.17   | 3.23   | 0.09  |
| P-phytate (g/100 g)             | 7.33  | 7.03   | 7.23   | 1.21  |
| P-phytate/P total (%)           | 81.00 | 75.00  | 78     | 2.00  |
| Total alkaloids (TA) (g/kg)     | 0.42  | 0.27   | 0.30   | 0.07  |
| Gramine + gramineisomer (% TA)  | 8.00  | 0.00   | 4.00   | 0.42  |
| Epilupinine (% TA)              | 2.67  | 0.00   | 1.34   | 0.07  |
| Lupinine (% TA)                 | 70.24 | 63.29  | 66.77  | 4.45  |
| Sparteine (% TA)                | 19.11 | 33.6   | 26.36  | 2.65  |
| Ammodendrine (% TA)             | 0.00  | 3.12   | 1.56   | 0.11  |
| Total oligosaccharides (TO) (g/kg)| 103.45| 85.61 | 94.53 | 13.15 |
| Raffinose (% TO)                | 8.41  | 12.84  | 10.62  | 0.98  |
| Stachyose (% TO)                | 59.86 | 57.64  | 58.75  | 2.40  |
| Verbascose (% TO)               | 31.72 | 29.52  | 30.62  | 1.36  |
| Viscosity (cP)                  | 1.19  | 1.09   | 1.14   | 0.03  |
| ME for pigs (MJ/kg DM)          | 12.66 | 12.90  | 12.78  | 1.65  |

SD: standard deviation.

Table 10  Apparent total digestibility coefficients of CP, EE and gross energy—Experiment I.

| Digestibility coefficients (%) | Lord | Mister | SEM | p   |
|--------------------------------|------|--------|-----|-----|
| CP                             | 77.857| 77.052 | 1.859| 0.667|
| EE                             | 66.804| 70.549 | 4.230| 0.391|
| Gross energy                   | 80.636| 79.769 | 1.314| 0.526|

SEM: standard error of mean.

Table 11  Performance results—Experiment II.

| Item                  | Control | L20 | L40 | L60 | L80 | L100 | SEM | p    |
|-----------------------|---------|-----|-----|-----|-----|------|-----|------|
| Starter               |         |     |     |     |     |      |     |      |
| Initial BW (kg)       | 16.2    | 16.5| 16.1| 16.8| 16.7| 17.1 | 2.20| 0.501|
| Final BW (kg)         | 40.2    | 41.9| 40.1| 40.9| 39.7| 40.1 | 0.30| 0.334|
| BWG (kg)              | 24.0    | 25.4| 24.0| 24.1| 23.0| 22.9 | 0.30| 0.139|
| DBWG (g/d)            | 649     | 686 | 649 | 652 | 622 | 620  | 7.50| 0.139|
| FI (kg)               | 56.6    | 57.9| 57.6| 57.6| 57.7| 57.4 | 3.10| 0.024|
| FCR (kg/kg)           | 2.38    | 2.28| 2.41| 2.39| 2.54| 2.54 | 0.03| 0.151|
| Grower                |         |     |     |     |     |      |     |      |
| Final BW (kg)         | 76.1    | 77.6| 74.2| 75.1| 74.0| 74.0 | 3.63| 0.394|
| BWG (kg)              | 35.9    | 35.7| 34.1| 34.3| 34.3| 33.9 | 0.40| 0.538|
| DBWG (g/d)            | 1,024   | 1,020| 974 | 979 | 980 | 969  | 11.0| 0.538|
| FI (kg)               | 97      | 99.4| 98.9| 100 | 100 | 99.2 | 7.50| 0.161|
| FCR (kg/kg)           | 2.72    | 2.80| 2.92| 2.94| 2.94| 2.94 | 0.03| 0.144|
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Mister analyzed in this study differed in chemical composition from what was reported by Hanczakowska and Światkiewicz [16]. In the current research, a higher level of CF, ADF, NDF, EE and CA was found. The TA content was similar. The seeds of var. Lord possessed a slightly higher amount of CP and CF than found by Chilomer et al. [17] and Kasprowicz-Potocka et al. [18]. The seeds of var. Lord analyzed by Kasprowicz-Potocka et al. [18] were characterized by a favorable amount of P-phytate (5.9 g/kg vs. 7.3 g/kg...
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The seeds of both varieties were used in the digestibility study because they are different in anti-nutrient content. The Lord variety contains about twice more alkaloids (with gramine), more oligosaccharides and CF than the Mister. Moreover, the viscosity of seeds var. Lord (in a water solution) was approx. 10% higher, thereby affecting the digestibility of the nutrients. The determined ATTD of protein was approx. 77%, crude fat was approx. 66%-70% and gross energy was approx. 80%. There was no significant difference between the varieties. ATTD of CP in the var. Mister was lower than reported by Hanczakowska and Swiatkiewicz [16]. However, the EE digestibility coefficient was higher. The digestibility coefficient of CP and EE in var. Lord was lower than obtained by Chilomer et al. [17]. Froidmont et al. [25] proposed that α-galactosidases can bind nutrients in indigestible complexes. Protein particles could also bind with NDF and phytate, thereby reducing protein digestibility. Moreover, although the overall digestibility of the DM and energy in lupine seeds is relatively high, a considerable proportion of energy is digested in the hind gut due to the high amounts of the non-starch polysaccharides and galactosides present in seeds. Therefore, the energy from lupines that is available to the pig is likely to be lower than what is anticipated from its digestible energy and ME contents [26].

The substitution of SBM by YL did not reduce the performance of the animals. Similar results were obtained by Sóńta et al. [27] during fattening periods where the animals were fed diets containing 7.5% and 15% of YL (var. Mister). It is noteworthy that in the Starter phase, the pigs from all of the experimental groups consumed more feed ($p < 0.05$). This shows that the presence of alkaloids in the diet did not negatively affect feed palatability, even when 29% of sweet YL was present in the diet (group L100). Pigs are quite sensitive to dietary alkaloids, but it may depend not only on the total amount of alkaloids but also individual alkaloids [20]. Buraczewska et al. [28] found that pigs do not tolerate more than 0.12 g of alkaloids of L. albus in kg of the diet. The content of alkaloids more than 0.2 g/kg in case of L. angustifolius and alkaloids up to 0.45 g/kg of L. luteus decrease FI in pigs [20]. Lupine seeds var. Mister used in the experiments were low in alkaloid content. The
actual results were in agreement with Experiment III. In all of the fattening phases, pigs offered diets with YL, as a total replacement of SBM (Group IV), had similar results as the control. Gdala et al. [29] reported that the substitution of SBM by YL in 30% did not influence the FI compared with the control group. However, in the study by Bugnacka and Falkowski [30], the substitution of 75% and 100% SBM by YL reduced the FI of pigs.

In Experiment III, there was also no difference among the other groups and the control in the Grower and Finisher phases and in total fattening time. Although, in the Starter phase, the pigs from Groups I and V that were offered diets with the highest amount of RSM (23% and 31.5%, respectively) presented reduced gains (total and daily) compared with the control diet and with L100 diet. It is possible that, for young animals, a higher level of RSM is not convenient, which was also found in a previous study [8]. Kasprowicz-Potocka et al. [8], and Hanczakowska and Światkiewicz [16] did not report a negative effect on the replacement SBM by 30% (Grower period) and 100% (Finisher period) RSM and lupine seeds on the production results in pigs during the whole fattening period. However, animals fed with a mixture containing rapeseed cake and blue lupine seeds reached a significantly lower average daily gain during the Grower period compared to YL. This negative effect may be a response to the usage of a higher amount of RSM than that is recommended. Landero et al. [31], in experimental diets containing 5%, 10%, 15% and 20% of expeller-pressed canola, did not notice any negative effects on pigs’ performance (total glucosinolates content was 0.01 mmol/kg of feed). On the other hand, Schöne et al. [32] found a negative effect when 15% of rapeseed cake was present in the diet (glucosinolates 3.2 mmol/kg of feed).

5. Conclusions

In conclusion, sweet YL (var. Mister and Lord) is characterized by a high digestibility of protein and gross energy. YL and their mixture with RSM can be used as a partial or total substitution of SBM in pigs’ diet, but if the inclusion rate of rapeseed meal in a diet is higher, the growth intensity in pigs may decrease. In the Starter phase, more than 15% RSM in the diet can reduce pigs’ growth. When formulating a diet containing lupine seeds and rapeseeds meal, it is necessary to optimize the contents of individual nutrients, particularly energy and amino acids.

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