The effect of substitution of soybean meal with a mixture of rapeseed meal, white lupin grain, and pea grain on performance indicators, nutrient digestibility, and nitrogen retention in Popielno White rabbits

Cezary Zwoliński, Andrzej Gugolek, Janusz Strychalski, Dorota Kowalska, Iwona Chwastowska-Siwiecka and Małgorzata Konstantynowicz

ABSTRACT
Rabbits, bred under large-scale farming conditions, are fed pelleted complete feed containing extracted soybean meal (SBM), which is the protein source. In recent years, in certain areas of the world, a trend has emerged for the elimination of soybean meal from feed rations. The objective of the study was to determine the effect of the substitution of extracted SBM with a mixture of extracted rapeseed meal (RSM; 5–10%), white lupin (WL) grain (4–8%), and pea grain (3–6%) on production results, as well as nutrient digestibility and nitrogen retention in Popielno White rabbits. The ration for the control group (C) contained 15% extracted SBM, while the ration for the experimental group (E1) contained 7.5% extracted SBM, which was partially substituted with a mixture of extracted RSM, WL and pea grains. In the experimental group (E2) diet, soybean meal was completely substituted. The obtained results indicated that the partial or complete substitution of extracted SBM with extracted RSM, pea, and WL did not have a negative effect on production results, digestibility of nutrients, and nitrogen retention.

1. Introduction
Rabbits are primarily bred for meat. For testing, typical meat breeds or synthetic lines are most often used. Local breeds with a lower growth rate are used less frequently (Abdel-Ghany et al. 2000; Bielański et al. 2008; Lakabi-IOualitene et al. 2008; Kowalska & Bielański 2011; Lounaouci-Ouyed et al. 2014; Paci et al. 2014). These breeds are most often used in experiments on the extensive breeding and feeding systems. In Poland, only one native rabbit breed is found, namely, the Popielno White (PW). It is recommended not only for extensive household breeding, but also for intensive production systems (Kowalska & Bielański 2011). These rabbits are characterized by gains being slightly smaller than those of typical meat breeds, yet they are more resistant to adverse environmental conditions (Bielański et al. 2008).

Rabbits, similarly to other animal species bred under large-scale farming conditions, are fed pelleted complete feed containing extracted soybean meal (SBM), which is the basic protein source. In recent years, in certain areas of the world, particularly those where soybean is not cultivated, a trend has emerged for the elimination of extracted SBM from feed rations for most livestock. The reason reported for such a measure is the willingness to become independent from imported feed, or the fear of products containing Genetically Modified Organisms (Tudisco et al. 2006). As regards the feeding of rabbits, the possibility for the substitution of soybean meal with other plant feeds containing significant amounts of proteins has been investigated. Most often, they were by-products of the agro-food industry. The use of barley, wheat, and corn dried distiller grains with solubles (DDGS) (Chelmińska & Kowalska 2013; Alagón et al. 2014; Strychalski, Juśkiewicz et al. 2014; Gugolek et al. 2015), sunflower cake (Volek & Marounek 2009; Volek & Marounek 2011), and rapeseed cake (Dänicke et al. 2004; Gasmi-Boubaker et al. 2007; Strychalski, Juśkiewicz et al. 2014; Gugolek et al. 2015) has already been studied. Moreover, attempts to use the grain of white lupin (WL) (Volek & Marounek 2009; Volek & Marounek 2011; Volek et al. 2013), pea (Séroux 1988; Castellini et al. 1991; Bonomi et al. 2003), and other plants of the Fabaceae family have been made (Amaefule et al. 2005; Lounaouci-Ouyed et al. 2014). Production results of the animals in experimental groups in these experiments were mostly positive. However, the above-mentioned feeds, in larger amounts, may have an adverse effect on animals, which, for by-products, is a result of the chemical and amino acid composition being changed in relation to the initial raw material, and for the grain of Fabaceae plants, is a result of various anti-nutritional substances, for example, tannins, antitrypsin factor, haemagglutinins, α-galactosides, and alkaloids (Bastianella et al. 1998; Kasprowicz & Frankiewicz 2003; Chilomer et al. 2010). The grain of Fabaceae plants...
may be subjected to treatment processes such as soaking after roasting, boiling, germination, fermentation, and alkaline treatments. Chemical treatment of lupin grain is the most common processing method suggested to reduce the alkaloid content of the crop (Arslan & Seker 2002; Falcão e Cunha et al. 2008).

In the context of the cited studies, it is evident that these feeds, when applied in moderate amounts, even when not subjected to any treatment processes, do not have an adverse effect on rabbits. A good solution may be the substitution of extracted SBM with a mixture of several various feeds added in smaller amounts, whose nutritional value and amino acid composition are similar to the composition of soybean meal. Lounaouci-Ouyed et al. (2014) studied the effects of the substitution of soybean meal on production results, as well as nutrient digestibility and nitrogen retention in PW rabbits.

2. Material and methods

2.1. Animal protocol

Sixty rabbits (30 females and 30 males) of the PW breed were used in the experiment; they were divided into 3 groups being analogous in terms of origin, proportion of gender, and used in the experiment; they were divided into 3 groups.

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2.2. Dietary treatment

The ration for the control group (C) contained 15% extracted SBM, while the ration for the first experimental group (E1) contained 7.5% extracted SBM, which was partially substituted with a mixture of extracted RSM, and WL and pea grains. In the second experimental group (E2), soybean meal was completely substituted (Table 1). The feeds were balanced through the manipulation of the amounts of cereal components in terms of chemical, amino acid, and energy composition, so that they were similar to a feed containing soybean meal (Table 2). All rations met the nutritional requirements of growing rabbits (Lebas, 2004). The chemical compositions of extracted SBM, extracted RSM, grains of WL of the Wat variety, and grains of peas (P) of the Mecenas variety are provided in Table 3.

2.3. Experimental procedures

During the nutritional experiment, the animals were weighed on electronic scales with an accuracy of 1 g, and their body weight (BW) was determined on days 35, 42, and 91 of life. Daily body weight gains (BWG) and FCR per 1 kg BWG were calculated. During the digestibility and balance testing, non-ingested feed residues and excreted faeces were collected every day, and weighed with an accuracy of 1 g. The collected faeces were frozen and then samples of faeces and feed mixtures were dried and ground. Urine was preserved with 20% sulphuric acid to allow calculating the total volume of collected urine at the end of the experiment. Thus, prepared samples were subjected to chemical composition and energetic value determination.

The balance method used in studies of this type enabled calculating digestibility coefficients of nutrients and energy as well as nitrogen (N) retention. Digestibility of nutrients (DN) was calculated. Digestibility coefficients of nutrients and energy as well as nitrogen (N) retention. Digestibility of nutrients (DN) was calculated.

Table 1. Ingredients of feed mixtures (%).

| Specification                  | C   | E1  | E2  |
|-------------------------------|-----|-----|-----|
| Soybean meal (48% CP)         | 15.0| 7.5 | –   |
| Rapeseed meal                 | –   | 5.0 | 10.0|
| White lupin seed              | –   | 4.0 | 8.0 |
| Pea seed                      | –   | 3.0 | 6.0 |
| Barley                        | 14.5| 12.5| 10.5|
| Wheat                         | 6.0 | 7.5 | 9.0 |
| Corn                          | 16.0| 12.5| 9.0 |
| Dried alfalfa (18% CP)        | 23.0| 23.0| 23.0|
| Wheat bran                    | 11.0| 11.0| 11.0|
| ARBOCELb                      | 6.0 | 5.5 | 5.0 |
| Beet molasses                 | 2.0 | 2.0 | 2.0 |
| Skimmed milk powder           | 2.0 | 2.0 | 2.0 |
| Dried brewer’s yeast          | 1.0 | 1.0 | 1.0 |
| Calcium carbonate             | 1.0 | 1.0 | 1.0 |
| Dicalcium phosphate           | 1.0 | 1.0 | 1.0 |
| Mineral–vitamin premixb       | 1.0 | 1.0 | 1.0 |
| NaCl                          | 0.5 | 0.5 | 0.5 |
| Total                         | 100.0| 100.0| 100.0|

bCrude fibre concentrate.

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Table 2. Chemical composition of feed mixtures (% of DM).

| Specification          | Group |
|------------------------|-------|
|                        | C     | E1    | E2    |
| Dry matter             | 89.78 | 90.03 | 89.83 |
| Crude ash              | 7.38  | 7.70  | 7.30  |
| Crude protein          | 19.27 | 19.34 | 19.31 |
| Ether extract          | 3.37  | 2.77  | 2.99  |
| Crude fibre            | 12.76 | 12.45 | 12.89 |
| NDF<sup>a</sup>        | 32.22 | 31.56 | 31.56 |
| ADF<sup>b</sup>        | 14.38 | 15.67 | 17.28 |
| ADL<sup>c</sup>        | 3.97  | 3.82  | 4.45  |
| Lysine                 | 0.86  | 0.95  | 0.88  |
| Methionine + cystine   | 0.80  | 0.83  | 0.91  |
| Threonine              | 0.77  | 0.87  | 0.86  |
| Thryptophan            | 0.18  | 0.18  | 0.17  |
| Gross energy (MJ kg<sup>-1</sup>) | 15.67 | 15.61 | 15.63 |

Notes: aNDF: neutral detergent fibre; bADF: acid detergent fibre; cADL: acid detergent lignin.

Table 3. Chemical composition of SBM, RSM, WL Wat variety, and pea Mecenas variety (P) (% of DM).

| Specification | SBM | RSM | WL | P   |
|---------------|-----|-----|----|-----|
| Dry matter    | 89.66 | 90.11 | 90.34 | 88.85 |
| Crude ash     | 6.98  | 7.12  | 4.53  | 3.52 |
| Crude protein | 50.40 | 36.46 | 43.37 | 24.29 |
| Ether extract | 20.64 | 4.20  | 4.45  | 1.29 |
| NDF<sup>a</sup> | 15.41 | 24.07 | 29.32 | 11.71 |
| ADF<sup>b</sup> | 7.56  | 14.25 | 21.68 | 7.35 |
| ADL<sup>c</sup> | 4.23  | 4.98  | 5.09  | 4.12 |
| Lysine        | 2.65  | 3.85  | 1.52  | 1.70 |
| Methionine + cystine | 1.13  | 1.61  | 0.83  | 0.68 |
| Threonine     | 1.53  | 1.82  | 1.24  | 0.95 |
| Thryptophan   | 0.46  | 0.49  | 0.30  | 0.25 |
| Gross energy (MJ kg<sup>-1</sup>) | 14.53 | 11.79 | 12.34 | 12.09 |

Notes: aNDF: neutral detergent fibre; bADF: acid detergent fibre; cADL: acid detergent lignin.

calculated from the following formula: DN(%) = (a – b)/a × 100, where ‘a’ denotes the nutrient content in a feed mixture and ‘b’ in faeces (Perez 1995).

After the feeding experiment, followed by 24-h fasting, the animals were weighed and killed according to the accepted recommendations for euthanasia of experimental animals. Dead rabbits were skinned and eviscerated. The following data related to slaughter performance were collected: rabbit BW before slaughter and chilled carcass weight (CCW, after 24-h chilling), which allowed calculating dressing percentage (DP) according to the formula provided by Blasco and Ouhayoun (1993): DP = CCW (without head and giblets)/BW × 100%. In addition, the percentage content of the most valuable elements: forepart, loin, and hind part, was calculated in the carcass. Head was dissected by a cut at the occipital joint; the forepart was dissected by a cut between the 7th and 8th thoracic vertebrae; loin – by cutting between the 6th and 7th lumbar vertebrae; and the hind part was the part of the carcass remaining after dissection of loin fore and included the peri-sacral area with hind legs (Daszkiewicz et al. 2012).

2.4. Analytical methods

2.4.1 Chemical analyses

The nutrient content of feed mixtures, nutrient excretion in faeces, and urinary nitrogen were determined by standard methods (AOAC 2006). Dry matter (DM) content (method 978.10) was determined after drying the samples in a dryer at 103°C. Crude ash (CA) content (942.05) was estimated by sample mineralization in a muffle furnace (Czylok, Jastrzębie Zdrój, Poland), at 600°C. Total nitrogen content (984.13) was determined by the Kjeldahl method, in the FOSS TECATOR 2200 Kjeltec Auto Distillation Unit. Ether extract (EE) content (920.39) was determined by the Soxhlet method in the FOSS TECATOR SOXTEC SYSTEM 2043 Extraction Unit. Finally, neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were estimated in the Foss Tecator Fibertec™ 2010 System. NDF was determined according to the procedure of Van Soest et al. (1991). ADF and ADL were determined according to the procedures of AOAC (2006). The levels of amino acids in the diets were determined using the Biochrom 20 plus amino acid analyser and Biochrom amino acid analysis reagents (Biochrom Ltd., Cambridge, England) (Official Method 982.30, AOAC 2006). Gross energy (GE) content was determined using a bomb calorimeter (IKA® C2000 basic, Staufen, Germany).

2.4.2. Statistical analysis

Data are expressed as means ± standard error of the mean (SEM). The results were statistically analysed using one-way analysis of variance (ANOVA), and significance of differences among groups was determined with the Duncan multiple range test at a significance level of P equal to or less than .05. All calculations were made with Statistica 10.0 (StatSoft 2011).

3. Results

The animals, during the entire study period, were in good health, and no death losses were noted. Table 4 presents the production performance of the rabbits. Although certain small
differences between the groups occurred, no statistical differences were found for any of the studied parameters among groups.

At the beginning of the experiment, the mean BW was similar in all groups, and ranged from 751.75 to 768.79 g (P > .05). Also on day 42, upon the commencement of the digestibility and balance testing, the rabbits’ BW was levelled. The final weight of rabbits in all groups was also similar. In the E2 group, it amounted to 2443.18 g, in the E1 group to 2444.41 g, and in the C group to 2466.15 g (P > .05).

Similarly to BW, the daily BWG was similar in all groups, and ranged from 29.98 g in the E2 group to 30.32 g in the C group. In turn, feed intake per 1 kg BWG was very similar in all groups, and ranged from 3.61 kg to 3.65 kg (P > .05).

The experimental factor appeared to have no impact on DP, which ranged from 47.99 in the C group to 48.11 in the E2 group (P > .05).

Also, the content of the forepart, loin, and hind part in carcass did not differ among the groups.

Table 5 presents the coefficients of nutrients and energy digestibility. The obtained results were slightly lower in the E2 group than in the C and E1 groups, yet with no statistical differentiation. The exception was ADF, which was highest in the E1 group, and lowest in the C group (P > .05). On the other hand, the results obtained in the E1 group were higher than those obtained in the C group for DM, OM (organic matter), CP (crude protein), ADF, and GE (P > .05) and lower than those for EE, NDF, and ADL (P > .05). As regards these components, no statistical differences between the groups were found, either.

Nitrogen intake showed no statistical differences, was similar in all groups, and fluctuated between 3.92 g d⁻¹ in the C group and 4.02 g d⁻¹ in the E2 group (P > .05) (Table 6). N excretion with faeces and urine was similar in all groups. It needs to be noted, however, that in the experimental groups, these values were slightly higher. The differences, however, were not statistically significant. The level of N retention ranged from 1.38 g in the E2 group, through 1.39 g in the E1 group, to 1.44 g d⁻¹ in the C group (P > .05).

Retention with respect to intake N showed no statistically significant differences. It was the highest in the C group – 36.67, and the lowest in the E2 group – 34.54%. Similarly, retention with respect to N digestion was highest in the C group – 50.60%, and the lowest in the E1 group – 47.62%.

4. Discussion

Average initial and final weights of rabbits in all groups, presented in Table 4, were similar to the data reported by Kowalska and Bielański (2011). These authors, based on a several-year-long study, established that PW rabbits aged 35 days are characterized by a BW ranging from 689.8 to 757.0 g, and at the age of 90 days, they reached a weight ranging from 2400.0 to 2434.3 g. This is confirmed by the results of a study by Topczewska et al. (2013); in their study, PW rabbits on day 35 of life weighed 726.8 g. In view of these data, the initial and final BW of PW rabbits in all groups should be considered typical of the breed. The obtained average daily gains of rabbits, and the FCR per 1 kg of gain, were also typical of this breed, and similar to the values reported by Kowalska and Bielański (2011).

On the other hand, the slaughter yield was similar to that calculated using the same method, and presented by Bielański et al. (2008) – 48.4%. Similar results were achieved by Daszkiewicz et al. (2012) in New Zealand White Rabbits, in an extensively fed group. In turn, as regards typical rabbits bred for meat, the slaughter yield calculated using this method is usually higher, and exceeds 50% (Zita et al. 2007; Volek & Marounek 2009; Gugolek et al. 2011; Strychalski, Juśkiewicz et al. 2014; Gugolek et al. 2015).

The content of the forepart, loin, and hind part in the carcass did not differ among the groups. The contribution of cuts in rabbit carcass is determined by the adopted dissection lines, age and breed of rabbits, and, to a lesser extent, the dietary regime (Szkucik & Libelt 2006). The results obtained in our study were similar to those obtained in a study by Daszkiewicz et al. (2012) and Gugolek et al. (2015).

The results for BW, BWG, and FCR in all groups were similar, and, as previously demonstrated, typical of the PW breed. However, they were lower than those for typical meat rabbits kept under similar conditions and fed feeds with a similar nutritional value (Strychalski, Juśkiewicz et al. 2014; Gugolek et al. 2015). Based on the data presented above, it should be considered that both partial and complete elimination of extracted SBM from the rations, and the substitution thereof with extracted RSM, WL, and peas, had no effect on the production results of rabbits. This was probably due to the similar response of PW rabbits to rations with a similar chemical composition (Table 1), nutritional and energy value, and amino acid composition (Table 2). Studies by other authors demonstrated that particular feeds, that is, RSM, and pea and lupin grains, which were used to substitute soybean meal, did not cause a significant reduction in production results, either. For example, Gasmi-

Table 5. Nutrients digestibility (%) in rabbits (mean ± SEM, n = 10).

| Specification       | C         | E1        | E2        | P        |
|---------------------|-----------|-----------|-----------|----------|
| Dry matter          | 70.43 ± 1.03 | 70.65 ± 1.43 | 68.65 ± 2.36 | <0.01    |
| Organic matter      | 72.15 ± 0.99 | 72.31 ± 1.36 | 70.83 ± 2.24 | >0.05    |
| Crude protein       | 72.32 ± 1.97 | 72.70 ± 1.14 | 71.59 ± 2.29 | >0.05    |
| Ether extract       | 88.62 ± 1.33 | 86.94 ± 1.60 | 86.08 ± 1.53 | >0.05    |
| NDFb                | 52.61 ± 0.92 | 50.65 ± 1.50 | 45.34 ± 1.25 | >0.05    |
| ADLc                | 24.68 ± 1.29 | 20.33 ± 2.52 | 19.83 ± 2.70 | >0.05    |
| Gross energy        | 76.14 ± 0.96 | 76.36 ± 1.23 | 75.63 ± 0.96 | >0.05    |

Notes: *NDF: neutral detergent fibre; aADF: acid detergent fibre; ADL: acid detergent lignin; SEM: standard error of the means.

A, B - Values with different superscripts are significantly different at P < 0.01.

Table 6. Nitrogen utilization in rabbits (mean ± SEM, n = 10).

| Nitrogen utilization (g d⁻¹) | C         | E1        | E2        | P        |
|-----------------------------|-----------|-----------|-----------|----------|
| Intake                      | 3.92 ± 0.18 | 4.09 ± 0.29 | 4.02 ± 0.18 | >0.05    |
| Excretion with faeces       | 1.06 ± 0.07 | 1.07 ± 0.08 | 1.13 ± 0.05 | >0.05    |
| Excretion with urine         | 1.42 ± 0.14 | 1.63 ± 0.23 | 1.51 ± 0.14 | >0.05    |
| Digestion                   | 2.86 ± 0.17 | 3.02 ± 0.24 | 2.89 ± 0.15 | >0.05    |
| Retention                   | 1.44 ± 0.05 | 1.39 ± 0.03 | 1.38 ± 0.04 | >0.05    |

Notes: *SEM: standard error of the means.
Boubaker et al. (2007) demonstrated in their study that 7% dietary inclusion of RSM had no effect on production results. Results of experiments conducted by Strychalski, Juśkiewicz et al. (2014) and Gugołek et al. (2015) demonstrated that the replacement of SBM with 5% of rapeseed cake did not cause changes in daily BWG, FCR, or DP of rabbits. Volek and Marounek (2009) showed that the addition of 15% WL grain to the rabbits’ feed did not affect weight gain or FCR as compared to that in animals fed diets containing SBM. Pea grain was added to rations for rabbits by Seroux (1988), Castellini et al. (1991), and Bonomi et al. (2003). Their study results show that pea meal may account for as much as 30% of feed ration with no negative effect on production results, that is, BWG, FCR, and DP. Bononia et al. (2003) are of the opinion that pea meal is a valuable feed, and that it is possible to use it as a soybean substitute. On the other hand, Lounaouci-Ouyed et al. (2014) demonstrated that the 30% addition of peas had no effect on growth or feed consumption, but increased the conversion of feed per 1 kg of gain as compared with a feed containing SBM.

In other publications on the substitution of SBM with other feeds, the authors explain that the poorer production results may be due to the poorer amino acid composition of the experimental diets (Stein et al. 2006; Yang et al. 2010; Youssef et al. 2012). However, no such relationships occurred in the experiment concerned (Table 2). In addition, it needs to be assumed that the level of anti-nutritional substances was not sufficiently high in groups E1 and E2 to have an adverse effect. However, their level was not tested in the experiment.

Neither partial nor complete substitution of SBM with RSM, lupin, and pea grains contributed to the statistically significant differentiation of the DN and energy between the groups (Table 5). As in the case of production results, a similar chemical and amino acid composition of the rations probably resulted in the similar use thereof. The results of a study carried out by Gasmi-Boubaker et al. (2007) demonstrate that a 7% addition of RSM to feed mixtures for rabbits had no effect on the DN, which is consistent with the results of our experiment. On the other hand, studies by Strychalski, Juśkiewicz et al. (2014) and Gugołek et al. (2015) demonstrated that the substitution of 5% SBM with RSM slightly reduced the digestibility of TP, EE, and GE. On the other hand, Volek and Marounek (2009) and Volek et al. (2013) demonstrated that the addition of 15% WL grain and 5% WL grain hulls to the ration had no effect on the DN. In the study by Lounaouci-Ouyed et al. (2014), the GE and TP digestibility coefficients were similar to those in the groups fed diets containing SBM and field bean (Vicia faba L.), while being lower in the group fed feed with 30% pea grain added.

However, a trend should be noted that in the E2 group, the results for the DN were the lowest, except ADF. This trend is not difficult to explain since, as demonstrated above, no apparent negative effect of RSM or lupin on digestibility was noted. Only pea grains in greater amounts may reduce the DN (Lounaouci-Ouyed et al., 2014). It is, however, difficult to conclude that a 6% content of pea grain reduces digestibility. Other authors are of the opinion that the reduction in the level of nutrient digestibility may result from an increase in the NDF level in feed rations (Dong & Giang 2008). However, this was not the case in the experiment concerned (Table 2).

The DN is influenced not only by the composition of feed mixtures, but also by the age of rabbits (Fu-Chang et al., 2004; Tůmová et al. 2003). In the light of the results of other digestibility tests, the obtained results provided in Table 5 should be considered typical for animals aged 40–60 days.

The DM digestibility levels determined in our study were higher than those reported by Fu-Chang et al. (2004) – 63.5–66.6%. On the other hand, they were similar to those obtained by Volek and Marounek (2009), and lower than those obtained in studies by Lakabi-loodalitene et al. (2008), Strychalski, Juśkiewicz et al. (2014), and Gugołek et al. (2015) – 71–83%.

Coefficients of CP digestibility were similar to those obtained in studies by Tůmová et al. (2003), Zita et al. (2007), Lakabi-loodalitene et al. (2008), and Strychalski, Gugołek et al. (2014). A higher level of protein digestibility, exceeding 80%, was noted in studies by Strychalski, Juśkiewicz et al. (2014) and Gugołek et al. (2015) in groups of animals characterized by higher productivity.

Fat (EE) is relatively well digested by animals. The level of 86–88% obtained in the study is consistent with the levels obtained by other authors (Tůmová et al. 2003; Ondruška et al. 2010; Strychalski, Juśkiewicz et al. 2014; Gugołek et al. 2015). On the other hand, Fu-Chang et al. (2004) obtained a lower digestibility of EE, that is, from 70.1 to 73.6%.

The reported level of digestibility of NDF fractions, ADF, and ADL exhibits certain differentiation in study results. Most often, the results for the digestibility of NDF fall within the range 40–50% (Volek & Marounek 2011; Strychalski, Juśkiewicz et al. 2014; Gugołek et al. 2015). Other authors report results falling below 40% (Volek & Marounek 2009; Strychalski, Gugołek et al. 2014). ADL is converted by rabbits at a level of 25–32%, and ADL at a level over 10% (Volek & Marounek 2009; Strychalski, Juśkiewicz et al. 2014; Gugołek et al. 2015).

The level of energy digestibility should also be considered typical for rabbits fed complete feed. In certain studies the level was slightly higher; for example, in a study by Lakabi-loodalitene et al. (2008), it ranged from 71 to 76%; in a study by Strychalski, Juśkiewicz et al. (2014), from 78 to 83%; while in a study by Gugołek et al. (2015), from 80 to 84%. A slightly lower level of digestibility was noted by Volek and Marounek (2009) – from 66 to 69%, and by Volek et al. (2013).

Levels of N retention with respect to N uptake and digestion may be found as average (within lower limits) in all groups. A higher retention level was noted in other studies (Mashamaite et al., 2009; Strychalski, Juśkiewicz et al. 2014; Gugołek et al., 2015). Results obtained by those authors should be associated with the higher productivity of the rabbits they tested. On the other hand, results lower than ours were presented by Strychalski, Gugołek et al. (2014) in Californian and Flemish Giant rabbits aged 70 days, and thus after the period of intense growth.

The slightly poorer results for retention in the E2 group may be associated with the higher level of N excretion in faeces, which is difficult to interpret. The literature lacks studies on the effect of the tested feeds on the retention of N in rabbits. On the other hand, in rats a lower level of the retention of N was noted in groups fed diets with the addition of lupin seed meal (Lupinus angustifolius). Rahman et al. (1997) and Aguilera et al. (1986) are of the opinion that this component is
responsible for the increased excretion of N in the urine, which suggests disturbances in systemic N metabolism. In our study, a slight trend towards the effect of the experimental diets on an increase in the excretion of N in the urine was also noted, yet it was not related to the increase in the level of pea or lupin grain in the diet.

5. Conclusion
The results obtained from PW rabbits’ feeding indicated that the partial or complete substitution of extracted SBM with 5–10% of extracted RSM, 4–8% of WL, and 3–6% of pea did not have a negative effect on production results, DN, or N retention.

Disclosure statement
No potential conflict of interest was reported by the authors.

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