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The chemical composition and nutritive value of low- and high-tannin faba bean varieties

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ABSTRACT

A comparison was carried out of the chemical composition and nutritive value of three genotypes of faba beans: two with coloured flowers, Nadwiślański and the self-ending Tinos varieties, and one with white flowers, Caspar. Caspar seeds were heavier and had a lower hull proportion and lower crude protein content (27.2% DM). The largest differences were in the content of proanthocyanidins (condensed tannins) which ranged from 0.02% (Caspar) to 1.11% DM (Tinos). The proanthocyanidin content in dehulled seeds of coloured flower varieties was low (0.02%) and similar to that in the low-tannin variety, Caspar. The antitrypsic activity of the seeds varied, ranging from 3.4 TIU/mg (Caspar) to 7.4 TIU/mg (Tinos). The inositol phosphate (1.05-1.15% DM) and α-galactoside (2.1-2.4% DM) contents did not differ significantly. The new varieties, Caspar and Tinos, contained almost twice as much vicine and convicine (0.75% and 0.92%, respectively) as the traditional variety, Nadwiślański (0.36% DM).

True digestibility coefficients (TD) for seeds determined on rats differed significantly and were: for Caspar, 83.9; Tinos, 77.3 and Nadwiślański, 80.0. Replacing whole seeds with dehulled seeds significantly increased the digestibility of dietary protein, to 88.1, 88.3 and 84.9, respectively. The net protein utilization (NPU) of the Nadwiślański and Tinos seeds were similar (55.4 and 55.0, respectively) and significantly lower than the NPU of Caspar seeds (61.0). The protein efficiency ratio (PER) of whole seeds supplemented with methionine and tryptophan were similar (Caspar, 2.21; Nadwiślański, 2.18; Tinos, 2.03) and insignificantly lower than the PER of dehulled seeds (2.37, 2.32 and 2.25, respectively).

KEY WORDS: faba bean, antinutrients, proanthocyanidins, nutritive value, rats, protein

INTRODUCTION

The high content of antinutritional factors in the seeds of coloured-flower faba bean varieties lowers nutrient digestibility and utilization in the digestive tract of monogastric animals (Longstaff and Mac Nab,1991; Jansman et al., 1994). For this reason, interest in cultivating varieties with lower contents of these compounds, so-called "zero ANFs" is growing in many European countries. The first low-tannin variety of a white-flowering faba bean imported from Holland has been introduced in Poland. The cultivation of the low-tannin variety, as well as of new "self-ending" varieties, points to the need for fuller characterization of their feed value.

The objective of this study was to compare the chemical composition of seeds from a high yielding traditional variety and of white-flowering and "self--ending" varieties, and to determine to what degree the differences in the content of phenolic compounds affect the nutritive value of the protein in the seeds of the new varieties, as compared with the traditional variety, Nadwiślański. Moreover, the aim of the study was to examine the effect of dehulling the seeds on the differences in nutritive value as related to the differences in the level of phenolic substances in the seed hull.

MATERIAL AND METHODS

Material

Seeds of the Nadwiślański, Tinos and Caspar varieties from the 1992-1994 harvests, purchased from Polish Plant Cultivation Stations and imported from Holland (Caspar 1993) were used in this study. The weight of the seeds, seed hull proportion and basic chemical composition were analysed during three years, while the remaining components were determined in samples from one year (1993). The feeding experiments were carried out using seeds from the 1993 harvest.

Physical characteristics of seeds

Average seed weight was measured by weighing 1000 randomly chosen seeds ten times. Specific density was determined by a conventional method by measuring the volume of water displaced by a weighed sample of 20 seeds. The percentage proportion of seed hull was determined by manual separation of cotyledons and hulls in a sample of seeds weighing about 100 g. To standardize the conditions and facilitate the separation of cotyledons and hulls, the samples were dried at 40^0C.

Analytical methods

The chemical composition, i.e. dry matter, ash, crude protein. crude fat, crude fibre and dietary fibre contents were determined by standard methods (AOAC, 1990). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were determined according to Van Soest and Wine (1967). The cellulose content was calculated from the difference between the ADF and lignin contents, while hemicellulose was computed as the difference between the NDF and ADF contents.

Amino acid composition was assayed using an automatic Beckman Model 6300 analyzer after hydrolyzing samples in 6 N HCl. Sulphur-containing amino acids were determined after oxidizing the samples in formic acid, tryptophan was assayed after hydrolysis in barium hydroxide. Protein quality was characterized by the essential amino acid index according to Oser (EAAI), and the limiting amino acid score (CS) according to Block and Mitchell, using the composition of egg white as the standard.

Total phenolic compounds were determined according to Naczk and Shahidi (1989), based on the reaction of these compounds with the Folin-Ciocalteau reagent. The flavanol content was determined using the vanillin method (Price et al., 1978), and proanthocyanidins (condensed tannins) were assayed according to Oszmiański et al. (1988) using the coloured reaction of cyanidins in butanol-HCl. Trypsin inhibitor activity (TIA) was determined by the method of Kakade et al. (1974). HPLC was used to assay the following components after the appropriate preparation of the samples: according to Sandberg and Ahderinne (1986) to determine inositol phosphates, according to Bjerg et al. (1985) to determine vicine and convicine, and according to Muzquiz et al. (1992) to determine sugars from the raffinose family (α-galactosides).

Nutritive value of protein of whole and dehulled faba beans

A control diet containing casein and diets containing whole or dehulled seeds of the faba bean varieties were used in the feeding experiments. The diet compositions are given in Table 1. The methionine and tryptophan deficiency in the faba bean diets were offset by the addition of synthetic amino acids (0.25% and 0.05%, respectively), according to Pastuszewska et al. (1985). The protein content of the diets was about 10%.

The experiments were carried out on 56 Wistar rats aged 28-30 days weighing about 65 g. Each experimental group comprised 4 males and 4 females. The rats were housed individually in organic glass cages in rooms with controlled lighting (12 h), temperature 22-23°C and relative humidity 70%. The experiment lasted 4 weeks and the results, i.e. feed consumption, body weight gains, were used to

TABLE 1

Composition of diets, %

Components	Experimental diets						
	C	WN	WT	WC	DN	DT	DC
Casein	11.9	–	–	–	–	–	
Whole seeds:							
Nadwiślański	–	37.3	–	–	–	–	–
Tinos	–	–	38.5	–	–		
Caspar	–	–	–	46.8	–	–	–
Dehulled seeds:							
Nadwiślański	–	–	–	–	33.5	–	–
Tinos	–	–	–	–	–	35.2	–
Caspar	–	–	–	–	–	–	42.9
Soya oil	8.0	7.5	7.5	7.5	7.5	7.5	7.5
Mineral mixture[1]	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Vitamin mixture[2]	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DL-methionine	0.15	0.25	0.25	0.25	0.25	0.25	0.25
L-tryptophan	–	0.05	0.05	0.05	0.05	0.05	0.05
Maize starch	69.95	49.9	48.7	40.4	53.7	52.0	44.3
Crude protein	10.7	10.5	10.5	10.7	10.7	10.7	10.7

[1] mineral mixture (NRC. 1976) containing in 100 g: 73.5 g $CaHPO_4$; 8.10 g K_2HPO_4; 6.80 g K_2SO_4; 3.06 g NaCl; 2.10 g $CaCO_3$; 2.14 g $NaHPO_4$; 2.50 g MgO; 558 mg ferric citrate; 81 mg $ZnCO_3$; 421 mg $MnGO_3$; 33.3 mg $CuCO_3$; 0.7 mg KJ and 705 mg citric acid

[2] vitamin mixture (AOAC 1975) containing in 1 g: 2 000 IU vitamin A; 200 IU vitamin D_3; to IU vitamin E; 0.5 mg vitamin K; 200 mg choline; 10 mg p-aminobenzoic acid; 10 mg inositol; 4 mg niacin; 4 mg calcium pantathenate; 0.8 mg riboflavin; 0.5 mg thiamin; 0.5 mg pyridoxine; 0.2 mg folic acid; 0.04 mg biotin; 0.003 mg cobalamin; sucrose (supplement to 1 g)

TABLE 2

Weight, specific weigh, proportion of hull and chemical composition of seeds[1]

	Variety		
	Nadwiślański	Tinos	Caspar
Weight of 1000 seeds, g	$471.5^{B} \pm 51.0$	$447.7^{B} \pm 4.9$	522.2 ± 53.7
Specific weight, kg/m^3	$1321.9^{A} \pm 19.2$	$1265.2^{B} \pm 9.9$	$1254.1^{B} \pm 2.5$
Proportion of hull, %	$13.93^{B} \pm 0.65$	$14.26^{A} \pm 0.15$	$12.8^{C} + 0.42$
Dry matter, %	88.45 ± 0.77	88.7 ± 0.96	88.69 ± 0.58
Ash, % DM	3.28 ± 0.08	3.32 ± 0.13	3.43 ± 0.06
Crude protein, % DM	28.90 ± 1.84	28.61 ± 1.64	27.24 ± 3.07
Ether extract, % DM	0.93 ± 0.06	0.80 ± 0.08	1.14 ± 0.10
Dietary fibre, % DM	20.92 ± 1.81	21.05 ± 1.39	19.70 ± 1.25

[1] average values and standard deviations from 3-years investigations

calculate the protein efficiency ratio (PER). True digestibility of protein (TD) was determined on the basis of a 5-day faeces collection in the last week of the experiment. The amount of metabolic nitrogen excreted in the faeces, i.e. 46.3 mg/rat/5 days, was taken from Rakowska et al. (1978). In evaluating net protein utilization (NPU), the animals were kept in groups in cages with two males and two females per cage. The nitrogen content in the bodies of rats was determined on the basis of their water content after ten days of the experiment.

The significance of differences among groups was assessed using the Duncan test.

RESULTS AND DISCUSSION

Weight and basic chemical composition of seeds

Tinos seeds were lighter while Caspar seeds were distinctly heavier than the seeds of Nadwiślański variety. The average weight of 1000 seeds (from 448 to 522 g) was lower than that of 22 varieties of faba beans (560 ± 170 g) in the study by Wang and Überschär (1990). These authors also found that the low-tannin varieties had higher average weights of 1000 seeds, even over 700 grams. The share of seed hull was inversely proportional to the weight of the seeds (from 12.8% in Caspar to 14.3% in Tinos) and was within the 13-15% limits given by other authors as characteristic of faba beans (Bjerg et al.,1988; Wang and Überschär, 1990). According to Helsper et al. (1993) the proportion of faba bean hulls may range from 11.6 to 15.7%.

The crude protein content of the seeds was between 27.2 and 28.9% DM, which is slightly lower than that found in most European varieties (Bjerg et al., 1988). Caspar seeds had slightly less crude protein (27.2% DM). According to the data of Grosjean et al. (1995) the crude protein content in Caspar seeds was 26.5%, while in the seeds of another white-flowering variety, 34.7%. This may indicate that the Caspar variety stands out with its low protein content among

TABLE 3

Chemical composition of whole and dehulled seeds, % DM

	Whole seeds			Dehulled seeds			Hulls		
	Nadwiślański	Tinos	Caspar	Nadwiślański	Tinos	Caspar	Nadwiślański	Tinos	Caspar
Dry matter	89.05	89.1	89.31	89.47	89.52	88.86	91.94	92.87	92.32
Ash	3.26	3.47	3.37	3.36	3.78	3.41	2.86	3.07	2.98
Crude protein	30.08	29.08	24.18	33.27	31.69	26.20	5.32	5.47	5.74
Ether extract	0.99	0.88	1.25	1.09	1.00	1.40	0.15	0.15	0.16
Dietary fibre	22.81	22.05	21.01	14.59	13.58	12.65	76.40	73.10	80.60

seeds grown in 1993

the Dutch low-tannin varieties. The dietary fibre content of the beans varied proportionately to the proportion of the hull, and ranged from 19.7% (Caspar) to 21.05% DM (Tinos). The dietary fibre content corresponded to the maximum levels found in faba beans by Bjergegaard and Sørensen (1992). Dehulling increased the protein content from 29-30% to 32-33% in Nadwiślański and Tinos, and from 24 to 26% DM in Caspar seeds, and decreased the dietary fibre content from 21-22% to 13-14% DM, so that the ratio of protein to fibre increased from 1.4 g/g in whole seeds to 2.3 g/g in dehulled seeds (Table 3).

Amino acid composition of protein

The protein of the varieties under study had a similar amino acid composition and similar essential amino acid index (EAAI, 66.0-66.9) and limiting amino acid score(CS) (Table 4). The content of lysine, phenylalanine and tyrosine in protein was similar to the values given by other authors (Pastuszewska et al., 1993). All seeds had the low methionine and cystine contents that are characteristic of faba beans and are responsible for the relatively low CS that varied from 34.7 (Nadwiślański) to 38 (Caspar). The tryptophan content ranged from 0.91-1.01 g/16g N and was intermediate between the values given by Jansman et al. (1993), and Smulikowska and Chibowska (1993). Dehulling reduced the content of some amino acids to a certain extent (including lysine, phenylalanine, tyrosine, and tryptophan), and as a result caused a slight decrease in the essential amino acid index (65.2-66.2). The results of Smulikowska and Chibowska (1993) also show that dehulling faba beans does not affect negatively the amino acid composition of protein.

TABLE 4

Amino acid composition of whole and dehulled seeds g/16 g N[1]

	Whole seeds			Dehulled seeds		
Amino acid	Nadwiślański	Tinos	Caspar	Nadwiślański	Tinos	Caspar
HIS	2.64	3.04	3.33	2.88	3.14	3.29
LYS	6.08	6.08	6.44	5.65	5.93	6.22
PHE+TYR	7.25	7.34	7.35	7.02	6.73	6.92
MET+CYS	2.22	2.26	2.43	2.24	2.26	2.27
THR	3.03	2.89	2.94	3.05	2.92	3.05
TRP	0.91	1.01	0.95	0.89	0.94	0.94
ILE	4.00	4.14	4.18	4.25	4.05	4.21
LEU	7.15	7.20	7.13	7.57	7.10	7.32
VAL	4.43	4.49	4.50	4.53	4.29	4.58
CS (MET + CYS)	34.73	5.3	38.0	35.0	35.3	35.5
EAAI	66.0	66.3	66.9	65.5	64.4	66.2

[1] seeds grown in 1993

TABLE 5

Content of antinutritional factors in whole and dehulled seeds, % DM

Amino acid	Whole seeds			Dehulled seeds		
	Nadwiślański	Tinos	Caspar	Nadwiślański	Tinos	Caspar
Phenolic compounds:						
total phenols[2]	1.35	1.69	0.27	0.27	0.14	0.25
proanthocyanidine[3]	0.85	1.11	0.02	0.02	0.02	0.01
flavanols[4]	0.29	0.38	0.04	0.04	0.03	0.02
TIA, TUI/mg	6.32	7.39	3.45	4.30	3.89	4.00
Glycosides[5]:						
vicine	2.28	5.78	4.11	nd	nd	nd
convicine	1.39	3.38	3.43	nd	nd	nd
total	3.67	9.16	7.54	nd	nd	nd
Inositol phosphates	1.01	1.06	0.94	1.14	1.19	1.04
α-galactosides:						
stachyose	0.90	0.77	0.94	nd	nd	nd
raffinose	0.10	0.08	0.13	nd	nd	nd
verbascose	1.36	1.20	1.18	nd	nd	nd
total	2.36	2.05	2.25	nd	nd	nd

[1] seeds grown in 1993
[2] sinapic acid equivalent
[3] cyanidine chloride equivalent
[4] D-catechin equivalent
[5] not determined in dehulled seeds

Antinutritional factors content

The content of phenolic compounds (Table 5) in Caspar seeds (0.27% DM) was five to six times lower than in varieties with coloured flowers (Nadwiślański, 1.35%, Tinos, 1.69% DM). The proanthocyanin and flavanol contents were similar to the tannin content found by Wang and Überschär (1990) and Pastuszewska et al. (1993).

The total phenolic compound content, as well as of flavanols, in Nadwiślański and Tinos seeds was similar to the values determined by the same methods by Ortiz et al. (1993). The proanthocyanidin content differed clearly among varieties and ranged from 0.85% (Nadwiślański) and 1.11% (Tinos) to 0.02% (Caspar). In comparison with data from the literature (Wang and Überschär, 1990; Longstaff et al., 1993) the studied Polish coloured flowered varieties had a lower proanthocyanidin content than found in many European varieties.

Dehulling reduced the phenolic compound content to the levels characteristic for low-tannin varieties (0.02% DM). The total polyphenol and flavanol contents in dehulled seeds of all varieties were lower than found by Ortiz et al. (1993).

Whole Nadwiślański and Tinos seeds had two-fold higher antitrypsic activity, 6.3 and 7.4 TIU/mg, respectively, than Caspar seeds (3.4 TIU/mg). No major differences were found in antitrypsic activity among dehulled seeds (3.9-4.3 TIU/mg). This shows that the antitrypsic activity of faba beans determined by the method of Kakade et al. (1974) resulted to a large extent from their content of phenolic compounds. A similar conclusion can also be drawn from the results of Helsper et al. (1993).

The vicine and convicine contents in faba beans (Table 5) were within the range given by Griffths and Ramsay (1992), and the two new varieties, Caspar and Tinos, had almost twice as much glycosides as the traditional Nadwiślański (0.75%, 0.92% and 0.36% DM, respectively). No major differences were found in the content or composition of phytates in the seeds of the compared varieties (Table 5). Total inositol phosphates in the seeds were close to 1% DM. The content of sugars from the raffinose family was similar in all varieties (2.05-2.36% DM) and was within the range given by Lattanzio et al. (1986), i.e. 1.4 to 2.62%.

Nutritive value of protein from whole and dehulled faba beans

Table 6 presents the results of the feeding studies in which whole and dehulled faba beans were used. A distinct, albeit not statistically proven, differences in feed consumption were found. The intake of diets containing Caspar seeds was the highest (355 ± 31.2 g), that of the Tinos seed containing diets was the lowest (298 ± 20.3 g). These results partially support the observations of other authors that feed consumption significantly decreases as the polyphenol content in the feed increases (Jansman, 1993).

A significant effect of faba bean variety was found on the protein digestibility of the diets. Similarly as in the studies of other authors (Pastuszewska, 1985; Jansman, 1993), true digestibility (TD) of protein in seeds with higher polyphenol contents was lower. Similar TD values for faba bean protein in rats were obtained by other authors in experiments on the effect of polyphenols on protein digestibility (Bjerg,1988; Pastuszewska,1993). Dehulling caused a highly significant rise in TD by about 8 percentage units in the groups receiving diets containing Tinos and Nadwiślański seeds, and about 5 percentage units in the diet with Caspar seeds.

The NPU did not differ between the Nadwiślański and Tinos varieties (55.4 and 55.0, respectively), but was significantly higher in Caspar (61), which could have been the result of the higher sulphur amino acid content in the protein of this variety. Dehulling Caspar seeds significantly lowered the NPU from 61 to 56.1, i.e., proportionately to the differences in the CS of whole and dehulled seeds (38 and 35.5, respectively). No correlation was found between the polyphenol

TABLE 6

Results of nutritional experiments on rats

Diet[1]	Diet intake[2] g	Weight gain g	TD	NPU	PER
C	$306.8^{A} \pm 41.8$	$89.5^{Aa} \pm 18.7$	$93.3^{A} \pm 1.2$	$75,1^{Aa} \pm 1.1$	$2.72^{Aa} \pm 0.28$
WN	$340.4^{A} \pm 41.2$	$76.3^{abab} \pm 13.1$	$80.0^{D} \pm 1.2$	$55.4^{Bc} \pm 1.2$	$2.18^{Bbc} \pm 0.16$
WT	$298.2^{A} \pm 20.3$	$63.6^{Bb} \pm 5.4$	$77.3^{E} \pm 1.1$	$55.0^{Bc} \pm 2.3$	$2.03^{Bc} \pm 0.15$
WC	$355.5^{A} \pm 31.2$	$84.5^{ABa} \pm 14.1$	$83.9^{C} \pm 1.6$	$61.0^{Bb} \pm 1.3$	$2.21^{Bbc} \pm 0.23$
DN	$323.7^{A} \pm 48.1$	$80.8^{ABab} \pm 19.9$	$88.3^{B} \pm 1.6$	$57.6^{Bbc} \pm 2.3$	$2.32^{Bb} \pm 0.21$
DT	$319.7^{A} \pm 30.2$	$77.7^{ABab} \pm 14.0$	$84.9^{C} \pm 1.7$	$58.1^{Bbc} \pm 0.3$	$2.25^{Bbc} \pm 0.23$
DC	$336.5^{A} \pm 42.5$	$85.7^{ABa} \pm 19.0$	$88.1^{B} \pm 2.3$	$56.1^{Bc} \pm 0.7$	$2.37^{Bb} \pm 0.21$

[1] composition given in Table 1

[2] means from 8 observations in g/4-weeks test

mean with the same superscripts within a column are not significantly different with the Duncan's multiple range test: A, B – $P<0.01$; a, b – $P<0.05$

content in seeds and NPU, although such relationship was found in the study by Pastuszewska (1993). Alzueta et al. (1992) found a negative effect of phenols on NPU and TD but no effect on BV of diets containing tannin extracts from faba beans.

No significant differences were found in PER of the compared varieties, both if the diet contained whole or dehulled seeds. PER was the highest in diets with whole or dehulled Caspar seeds (2.21 and 2.37, respectively), and the lowest with whole or dehulled Tinos seeds (2.03 and 2.25, respectively), which contained larger amounts of proanthocyanidins. A similar tendency, i.e. a higher nutritive value of diets containing faba bean varieties with lower phenolic contents, was also found in studies on pigs (Grala, 1993) and on poultry (Smulikowska and Chibowska, 1993; Ortiz et al., 1994).

Dehulling seeds caused a distinct, although statistically nonsignificant, increase in the PER (Table 6). The highest rise, about 10%, the diet containing whole seeds, was noted for the Tinos variety that has the highest polyphenol content. It can be presumed that the rise in PER was the result of both the increased energy content of the diet with dehulled seeds (with a lower dietary fibre content) as well as of the lower content of polyphenols.

CONCLUSIONS

As compared with the Nadwiślański and Tinos varieties, the seeds of the white-flower variety, Caspar, were heavier and had a lower hull proportion, and a lower crude protein content. They contained small amount of polyphenols, had the lowest antitrypsic activity, and relatively high vicine and convicine contents.

The seeds of the new "self-ending" Tinos variety contained more phenolic polymers and vicine and convicine than Nadwiślański seeds. Dehulling the seeds of coloured flowering varieties decreased the proanthocyanidin content to a level characteristic for low-tannin varieties.

In the experiments on rats fed diets containing 35-47% faba beans, as the dietary proanthocyanidin content rose, the true digestibility of protein decreased significantly, PER declined insignificantly, and the NPU did not change. The use of dehulled coloured flower varieties in diets gave similar results as the addition of low-tannin seeds of a white flower variety. The better nutritional effects of dehulled seeds was partly the result of a lower dietary fibre content.

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STRESZCZENIE

Skład chemiczny i wartość odżywcza nasion nisko- i wysokotaninowych odmian bobiku

Porównano skład chemiczny i wartość odżywczą nasion trzech genotypów bobiku: odmian kwitnących kolorowo Nadwiślański i „samokończącej" Tinos oraz biało kwitnącej odmiany Caspar. Nasiona odmiany Caspar były cięższe i miały mniejszy udział okrywy nasiennej oraz mniejszą zawartość białka ogólnego (27,2% s.m.). Najbardziej zróżnicowaną była zawartość proantocyjanidyn (tanin skondensowanych), która wynosiła od 0,02% (Caspar) do 1,11% s.m. (Tinos). W odłuszczonych nasionach odmian kolorowo kwitnących zawartość proantocyjanidyn była niska

(0,02%) i podobna jak w nasionach niskotaninowej odmiany Caspar. Aktywność antytrypsynowa nasion była zróżnicowana – od 3,4 TIU/mg (Caspar) do 7,4 TIU/mg (Tinos). Zawartość fosforanów inozytolu (1,05-1,15% s.m.) i α-galaktozydów (2,1-2,4% s.m.) nie różniła się istotnie. Nowe odmiany Caspar i Tinos zawierały ponad dwukrotnie więcej wicyny i konwicyny (odpowiednio 0,75% i 0.92%) w porównaniu z tradycyjną odmianą Nadwiślański (0,36% s.m.).

Współczynniki strawności rzeczywistej białka (TD) nasion oznaczone na szczurach różniły się istotnie i wynosiły: odmiany Caspar – 83,9, Nadwiślański – 80,0, Tinos – 77,3. Zastąpienie nasion całych nasionami odłuszczonymi spowodowało istotny wzrost strawności białka diet, odpowiednio do 88,1, 88,3 i 84,9. Wskaźnik wykorzystania białka netto (NPU) nasion odmian Nadwiślański i Tinos był zbliżony (odpowiednio 55,4 i 55,0) i istotnie niższy od wartości NPU nasion odmiany Caspar (61,0). Wskaźniki wydajności wzrostowej białka (PER) diet z udziałem całych nasion uzupełnionych metioniną i tryptofanem były zbliżone (Caspar – 2,21, Nadwiślański – 2,18, Tinos – 2,03) i nieistotnie niższe od PER białka nasion odłuszczonych (odpowiednio, 2,37; 2,32; 2,25).