AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura

VOL. LXXVII (1) 2022

https://doi.org/10.24326/as.2022.1.8

[1] Vocational State School of Ignacy Mościcki in Ciechanów,
Faculty of Engineering and Economics, Ciechanów, Poland
[2] Siedlce University of Natural Sciences and Humanities, Faculty of Agrobioengineering
and Animal Husbandry, Institute of Agriculture and Horticulture, Siedlce, Poland
* e-mail: rafal.gorski@puzim.edu.pl

RAFAŁ GÓRSKI[1]*, ANNA PŁAZA[2], ROBERT RUDZIŃSKI[1]

Changes in carbohydrate content in mixtures of field pea and spring triticale determining the quality of green fodder

Zmiany zawartości węglowodanów w mieszankach grochu siewnego z pszenżytem jarym decydujące o jakości zielonki

Summary. Green fodder obtained from mixtures of legume and cereals can be a good quality for direct feeding. Obtaining good quality fodder from mixtures cultivated on arable land is possible on the condition of proper share of components, harvest time and plant selection. The aim of this study was to evaluate the effect of the share of components in the mixture of pea with spring triticale and the harvest date on carbohydrates content in green matter. A field experiments were conducted from 2016 to 2018 and two factors were studied: I. Share of components in the mixture: field pea - clean sowing, spring triticale – clean sowing, field pea 75% + spring triticale 25%, field pea 50% + spring triticale 50%, field pea 25% + spring triticale 75%. II. Harvest date: flowering stage of field pea, flat green pod stage of field pea. The highest content of total carbohydrates and water-soluble carbohydrates, among the mixtures, was found in the mixture with 75% share of pea and 25% share of spring triticale. The harvest date had no effect on the concentration of total carbohydrates, while delaying the harvest date caused a decrease in the water-soluble carbohydrates content in the green matter of the mixtures.

Key words: field pea, spring triticale, mixtures, harvest date, carbohydrates

INTRODUCTION

On farms focused on intensive cattle production, special attention should be paid to the quality of roughage, which is largely the main nutrient in ruminant nutrition [Bilik and Strzetelski 2014]. According to Aufrere et al. [2008], the factor that determines the usefulness of forage in cattle feeding, besides the highest possible yield, is also its nutritive value. The use of feeds with a low nutritive value results in a longer finishing time and thus a higher consumption of roughage and concentrate feeds to supplement the nutrients present in deficiency [Litwińczuk et al. 2013]. As a result, this causes a significant increase in the cost of raising ruminants and thus a reduction in agricultural income. High quality roughage can be obtained from the cultivation of legume – cereal mixtures in the case of optimal selection of mixture components, harvesting date as well as appropriate selection of plants for the conditions in which they are grown. According to Oba [2010], feeding carbohydrates-rich forages to dairy cows increases overall dry matter intake as well as milk fat yield. According to Ondarza et al. [2020], increasing the amount of carbohydrates in ruminant diets decreases the amount of ammonia in the rumen, concluding that rapidly digested carbohydrates assist rumen microorganisms in nitrogen uptake and utilization. The authors also suggest that, additional carbohydrates in cattle feed increase fiber digestion, microbial protein synthesis and rumen pH. Also Klevenhusen and Zebeli [2020] reported that feeding water-soluble carbohydrates (WSC) rich feeds to cattle has a positive effect on rumen pH. Thus, feeding WSC rich feeds does not increase the risk of rumen acidosis [Taweel et al. 2005, Bertilsson et al. 2017] which can lead to other metabolic disorders [Humer et al. 2018]. This type of feed provides high milk yield, high yielding cows may however require temporary addition of concentrate feed in early lactation to be able to overcome the negative energy balance after parturition [Klevenhusen and Zebeli 2020]. The objective of this study was to determine the effect of component proportion in the mixture and harvest date on total carbohydrates (TC) and water-soluble carbohydrates in mixtures of pea and spring triticale.

MATERIAL AND METHODS

The field experiment was conducted in 2016–2018 at the Agricultural Experimental Station in Zawady belonging to the University of Natural Sciences and Humanities in Siedlce. The field was flat, water erosion did not occur. The experimental soil was Stagnic Luvisol, of very good rye complex, of valuation class of IVb soil. The content of available mineral elements in the soil was: P 81.0 mg kg^{-1}, K 122.0 mg kg^{-1}, Mg 52.0 mg kg^{-1}. The humus content was 13.9 g kg^{-1}. The experiment was set up in split – block design in three replications. The original plot size was 20 m^2 (5 m × 4 m) and the harvested plot area was 16 m^2 (4 m × 4 m). Two factors were studied in the experiment:

I. share of components in the mixture: field pea – pure sowing, spring triticale – pure sowing, field pea 75% + spring triticale 25%, field pea 50% + spring triticale 50%, field pea 25% + spring triticale 75%;

II. harvesting date: flowering stage of field pea (BBCH 65), flat green pod stage of field pea (BBCH 79). The detailed list of mixtures and their sowing rates: field pea 240 kg ha^{-1}, spring triticale 220 kg ha^{-1}, field pea 180 kg ha^{-1} + spring triticale 55 kg ha^{-1}, field pea 120 kg ha^{-1} + spring triticale 110 kg ha^{-1}, field pea 60 kg ha^{-1} + spring triticale 165 kg ha^{-1}. In all years of the study, experimental mixtures were preceded by oats. In autumn phosphorus and potassium fertilizers were applied in doses depending on the soil chemical composition, i.e. 34.8 kg ha^{-1} P in the form of 46% triple superphosphate and

99.2 kg ha^{-1} K in the form of 60% potassium salt. In spring, nitrogen fertilizers in the form of ammonium nitrate 34% were applied before sowing seeds. On all treatments, with the exception of pea grown in pure sowing, 30 kg N ha^{-1} was applied. At the stalk shooting stage, an additional 50 kg N ha^{-1} was applied for spring triticale and 30 kg N ha^{-1} for mixtures of pea with spring triticale. The seeds of pea ('Roch') and spring triticale ('Milewo') were sown in the 1st decade of April according to the first experimental factor. Sowing was carried out with a Mazur 5 type S052/C grain drill. The plants were harvested according to the second factor of the experiment: pea flowering stage (3rd decade of June) and pea flat green pod stage (1st decade of July). While harvesting of mixtures from each field, the fresh matter of 1 kg was acquired (the sample) for the chemical analysis. The sample was shredded and dried in the room with free air flow of ambient temperature. After drying the following estimates were made: total carbohydrates (TC) and water-soluble carbohydrates (WSC) the determination method used was near infrared spectroscopy (NIRS) and the spectrometer was a NIR Flex N-500. The method is described in detail in the Polish Standard called PN-EN ISO 12099:2010 and in the literature [Burns et al. 2010].

Each of the studied characteristics was subjected to analysis of variance according to the split-block design scheme. In case of significant sources of variability, detailed comparison of means was made with the use of Tukey's Test.

Temperature and precipitation conditions in the years of the study were varied (Tab. 1).

Table 1. Weather conditions during the growing season of field pea/spring triticale mixtures according to the Zawady Meteorological Station

Years	Month				Means
	IV	V	VI	VII	
	Temperature (°C)				
2016	9.1	15.1	18.4	19.1	15.4
2017	6.9	13.9	17.8	16.9	13.9
2018	13.1	17.0	18.3	20.4	17.2
Long-term mean 1990–2008	8.2	14.2	17.6	19.7	14.9
	Precipitation (mm)				Total
2016	28.7	54.8	36.9	35.2	155.6
2017	59.6	49.5	57.9	23.6	190.6
2018	34.5	27.3	31.5	67.1	160.4
Long-term mean 1990–2008	37.4	47.1	48.1	65.5	198.1

The 2016 growing season recorded an average temperature 0.5°C higher than the multi-year average. During the entire growing season, precipitation was of 42.5 mm lower compared to the multi-year total. In 2017, the average temperature during the growing season was 1°C lower than the multi-year average, in turn, the total precipitation was of 7.5 mm lower than the multi-year total. The average temperature recorded during the growing season in 2018 was of 2.3°C higher than the multi-year average. In contrast, total precipitation was of 37.7 mm lower than the multi-year total.

RESULTS

The content of TC in mixtures of pea with spring triticale was significantly modified by weather conditions, share of components in the mixture and their interaction. The highest content of TC was revealed in mixtures of pea with spring triticale harvested in 2018, significantly lower of 13.9 g kg^{-1} d.m. in 2016 and of 25 g kg^{-1} d.m. in 2017 (Tab. 2).

Table 2. Total carbohydrates content in field pea/spring triticale mixtures according to component share in the mixture in 2016–2018 (g kg^{-1} d.m.)

Composition of mixture (%)		Years			Means
field pea	spring triticale	2016	2017	2018	
100	0	264.8	254.4	286.5	268.6
75	25	194.7	169.5	217.6	193.9
50	50	167.0	158.7	183.6	169.7
25	75	130.3	118.4	134.5	127.7
0	100	86.8	87.2	91.0	88.3
Means		168.7	157.6	182.6	–
$LSD_{0.05}$					
Years (Y)					14.4
Composition of mixture (A)					22.1
Interaction (Y × A)					38.3

The share of components in the mixture also had a significant effect on the concentration of TC. The highest content of TC was found in pea grown in pure sowing and the lowest in spring triticale. Among the mixtures, the significantly highest content of TC was found in the mixture with a component share of 75% pea and 25% spring triticale. The interaction of weather conditions and the share of components in the mixture was revealed, which shows that the significantly highest content of TC was characterized by pea grown in pure sowing in all years of the experiment, at the significantly lowest level the concentration of TC was found in spring triticale grown in pure sowing during the entire period of the experiment and in the mixture with a share of components of 25% pea + 75% spring triticale harvested in 2017.

Weather conditions significantly differentiated the concentration of TC in mixtures of pea and spring triticale at the harvest dates studied (Fig. 1).

The highest value was revealed in mixtures harvested at the flowering stage of pea in 2018. Mixtures harvested in 2016 and 2017 regardless of harvest date and mixtures harvested in 2018 at the flat green pod stage of pea were characterized by comparable, significantly lower, TC.

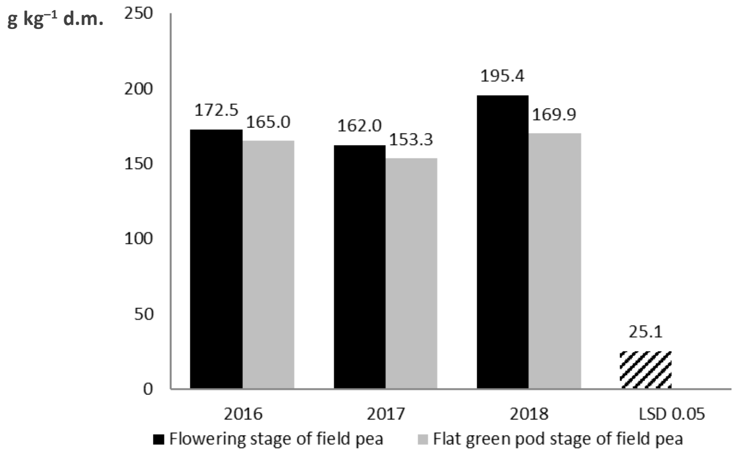

Figure 1. Total carbohydrates content in field pea/spring triticale mixtures according to harvest date in the research years 2016–2018

The harvest date did not significantly affect the concentration of TC in mixtures of pea and spring triticale (Tab. 3).

The mixtures harvested at the flat green pod stage of pea concentrated comparable values of TC as those harvested at the flowering stage of pea. The interaction of the proportion of components in the mixture and harvest date showed that the pea crop had significantly the highest TC content regardless of harvest date. The significantly lowest content of TC was found in spring triticale grown in pure sowing irrespective of the harvest date.

Table 3. Total carbohydrates content in field pea/spring triticale mixtures – means across 2016–2018 (g kg^{-1} d.m.)

Composition of mixture (%) – A		Harvest date	
field pea	spring triticale	flowering stage of field pea	flat green pod stage of field pea
100	0	268.1	269.0
75	25	200.9	186.9
50	50	175.4	164.0
25	75	143.9	111.6
0	100	94.6	82.0
Means		176.6	162.7
$LSD_{0.05}$			
Harvest date (B)			ns*
Interaction (A × B)			29.2

* ns – non-significant

Statistical analysis showed a significant effect of thermal and moisture conditions, the experimental factors studied and their interaction on the WSC content in mixtures of pea and spring triticale. The highest WSC content was determined in mixtures harvested in 2018, lower of 12.2 g kg^{-1} d.m. in 2016, and significantly lowest of 23.1 g kg^{-1} d.m. in 2017 (Tab. 4).

Table 4. Water-soluble carbohydrates content in field pea/spring triticale mixtures according to component share in the mixture in 2016–2018 (g kg^{-1} d.m.)

Composition of mixture (%)		Years			Means
field pea	spring triticale	2016	2017	2018	
100	0	164.6	158.5	175.8	166.3
75	25	120.6	106.1	137.6	121.4
50	50	110.6	96.6	121.7	109.6
25	75	88.3	73.6	100.9	87.6
0	100	70.1	64.6	79.1	71.3
Means		110.8	99.9	123.0	–
$LSD_{0.05}$					
Years (Y)					8.7
Composition of mixture (A)					13.3
Interaction (Y × A)					23.0

The proportion of components in the mixture also significantly differentiated the WSC concentration. The highest WSC content was revealed in pea grown in pure sowing and the lowest in spring triticale. Additionally, it was found that mixtures with the share of 75% pea + 25% spring triticale and with equal share of both components contained comparable WSC contents. The interaction between weather conditions and the share of components in the mixture was demonstrated and it resulted that the highest WSC concentration was characterized by pea in all years of the study.

Growing season conditions also differentiated the WSC concentration in mixtures of pea and spring triticale at harvest dates analyzed in the experiment (Fig. 2). The highest WSC content was found in the 2018 mixtures harvested at the flowering stage of pea. Its significantly lowest content was of 47.4 g kg^{-1} d.m. recorded in 2016 and of 59.4 g kg^{-1} d.m. in 2017 mixtures of field pea and spring triticale harvested at the flat green pod of field pea.

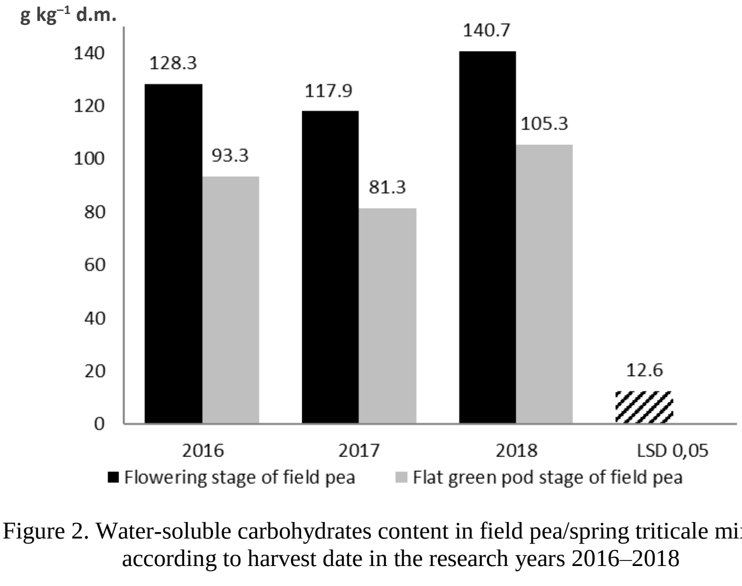

Figure 2. Water-soluble carbohydrates content in field pea/spring triticale mixtures according to harvest date in the research years 2016–2018

Table 5. Water-soluble carbohydrates content in field pea/spring triticale mixtures – means across 2016–2018 (g kg^{-1} d.m.)

Composition of mixture (%) – A		Harvest date	
field pea	spring triticale	flowering stage of field pea	flat green pod stage of field pea
100	0	198.9	133.6
75	25	139.4	103.4
50	50	90.1	129.1
25	75	98.1	77.1
0	100	79.4	63.1
Means		129.0	93.5
$LSD_{0.05}$			
Harvest date (B)			7.3
Interaction (A × B)			12.5

The harvest date significantly modified the concentration of WSC in mixtures of pea with spring triticale (Tab. 5). The mixtures harvested at the flowering stage of pea were characterized by a significantly higher of 35.5 g kg^{-1} d.m. WSC content than those harvested at a later developmental stage of the legume plant. The interaction between the proportion of components in the mixture and the harvest date was demonstrated, showing that pea harvested at the flowering stage had the highest WSC content. Among the mixtures, the highest concentration of WSC was revealed in mixtures with 75% share of pea and 25% of spring triticale harvested at the flowering stage field pea and a mixture with equal share of both components harvested at the flat green pod stage of field pea.

DISCUSSION

The content of TC and WSC in the green fodder of mixtures of peas with spring triticale determines the quality of the obtained fodder for cattle feeding. In our study, the highest content of TC and WSC was recorded in mixtures of peas with spring triticale harvested in dry 2018, and significantly lower in 2016 and 2017. An analogous relationship was recorded in their study by Carvalho [2005], Gill and Omokanye [2016, 2018] and Rad et al. [2020]. Also other authors [Nazarli and Faraji 2011, Izanloo et al. 2008, Carvalho et al. 2004] have shown higher carbohydrates content in legume and cereal crops as a result of reduced water availability. This is due to the fact that with less rainfall during the growing season, the concentration of nutrients, including TC and WSC content, increases in plants. In the present experiment, analyzing the carbohydrates content in plants depending on the share of components in the mixture, a higher carbohydrates content was recorded in pea than in spring triticale. This is confirmed by the results of other authors' studies on the cultivation of different legume/cereal mixtures [Mustafa and Seguin 2004, Nazarli and Faraji 2011, König et al. 2017, Brown et al. 2018, Ferreira et al. 2017, Jilani et al. 2018, Omokanye et al. 2019, Rad et al. 2020]. In our study, analogously to the studies of Mustafa and Seguin [2004], Nazarli and Faraji [2011], Brown et al. [2018] and Jilani et al. [2018], the addition of a legume crop to cereal mixtures increased the carbohydrates content of green fodder. In the present experiment, the highest content of TC and WSC was recorded in the mixture of pea and spring triticale with 75 + 25% components. In the study of Salama [2020], the highest non-fibre carbohydrates content was recorded in the green forage of berseem clover mixtures with cereals with component shares of 50 + 50% and 75 + 25%. Baghdadi et al. [2016] also recorded the highest WSC content in corn-soybean mixtures with component shares of 75 + 25% and 50 + 50%. In our study, analogously to the study of Brown et al. [2018] and Salama [2020], the mixtures with the lowest share of legume crop were characterized by the lowest carbohydrates content.

In the present experiment, the harvest date of mixtures of pea with spring triticale significantly differentiated the content of TC and WSC in green fodder. Field pea and spring triticale mixtures harvested at the field pea flowering stage were characterized by a higher WSC content than those harvested at the stage of the flat green pea pod. An analogous relationship in their studies on other legume-cereal mixtures was noted by other authors [König et al. 2017, Maxin et al. 2017, Marković et al. 2020]. Also Faligowska et al. [2014] in their experiment showed a decrease in the concentration of WSC in the green matter of white lupin with a delay in the harvest date, which is consistent with the results obtained in our study.

According to Klevenhusen and Zebeli [2020], providing dairy cattle with a WSC content of 150-200 g kg^{-1} d.m. allows to reduce the inclusion of supplement concentrates in diets, while improving rumen health and sustainable milk production. The level of WSC content obtained in our study in the mixture with 75% of pea and 25% of spring triticale components harvested at the flowering stage of legume plant is slightly lower, so one can expect a positive effect of feeding such green forage on dairy cattle.

CONCLUSIONS

The highest carbohydrate and water-soluble carbohydrates concentration in mixtures of field pea and spring triticale was revealed in the year with the lowest sum of precipitation. Among the mixtures, the highest content of total carbohydrates and water-soluble carbohydrates was recorded in the mixture of field pea with spring triticale with the share of components 75 + 25%. Mixtures of field pea and spring triticale harvested at the flat green pod stage of field pea concentrated a similar content of total carbohydrates as mixtures harvested at the flowering stage of field pea, but less water-soluble carbohydrates.

REFERENCES

Aufrere J., Carrere P., Dudilieu M., Baumont R., 2008. Estimation of nutritive value of grasses from semi-natural grasslands by biological, chemical and enzymatic methods. Grassl. Sci. Eur. 13, 426−428.

Baghdadi A., Halim R.A., Ghasemzadeh A., Ebrahimi M., Othman R., Yusof M.M., 2016. Effect of intercropping of corn and soybean on dry matter yield and nutritive value of forage corn. Legum. Res. 39, 976−981. https://doi.org/10.18805/lr.v39i6.6643

Bilik K., Strzetelski J., 2014. Żywienie bydła mięsnego w warunkach chowu ekologicznego z uwzględnieniem badań Instytutu Zootechniki PIB. Wiad. Zootech. 52, 23−44.

Bertilsson J., Åkerlind M., Eriksson T., 2017. The effects of high-sugar ryegrass/red clover silage diets on intake, production, digestibility, and N utilization in dairy cows, as measured in vivo and predicted by the NorFor model. J. Dairy. Sci. 100(10), 7990−8003. https://doi.org/10.3168/jds.2017-12874

Brown A.N., Ferreira G., Teets C.L., Thomason W.E., Teutsch C.D., 2018. Nutritional composition and in vitro digestibility of grass and legume winter (cover) crops. J. Dairy Sci. 101(3), 2037−2047. https://doi.org/10.3168/jds.2017-13260

Burns G.A., Gilliland T.J., McGilloway D.A., O'Donovan M., Lewis E., Blount N., O'Kiely P., 2010. Using NIRS to predict composition characteristics of *Lolium perenne* L. cultivars. Adv. Anim. Biosci. 1(1), 321−321. https://doi.org/10.1017/S2040470010004644

Carvalho I.S., Pinto Ricardo C., Chaves M., 2004. Quality and distribution of assimilates within the whole plant of lupins (*L. albus* and *L. mutabilis*) influenced by water stress. J. Agron. Crop Sci. 190(3), 205−210. https://doi.org/10.1111/j.1439-037X.2004.00094.x

Carvalho I.S., 2005. Effects of water stress on the proximate composition and mineral contents of seeds of two lupins (*Lupinus albus* and *Lupinus mutabilis*). J. Food Qual. 28, 325−332. https://doi.org/10.1111/j.1439-037X.2004.00128.x

Faligowska A., Selwet M., Panasiewicz K., Szymańska G., 2014. Quality and hygienic conditions of white lupin silage, affected by forage stage of growth and use of silage additives. Turk. J. Field Crops. 19(2), 252−257. https://doi.org/10.17557/tjfc.18561

Ferreira G., Brown A.N., Thomason W.E., Teutsch C.D., 2017. Comparative nutritional quality of winter crops for silage. Virginia Tech. 0117/DASC-93P, 1−5.

Gill K.S., Omokanye A.T., 2016. Spring triticale varieties forage yield, nutrients composition and suitability for beef cattle production. J. Agric. Sci. 8(10), 1−14. http://doi.org/10.5539/jas.v8n10p1

Gill K.S., Omokanye A.T., 2018. Potential of spring barley, oat and triticale intercrops with field peas for forage production, nutrition quality and beef cattle diet. J. Agric. Sci. 10(4), 1−17. https://doi.org/10.5539/jas.v10n4p1

Humer E., Petri R.M., Aschenbach J.R., Bradford B.J., Penner G.B., Tafaj M., Sudekum K.H., Zebeli Q., 2018. Invited review: practical feeding management recommendations to mitigate the risk of subacute ruminal acidosis in dairy cattle. J. Dairy. Sci. 101(2), 872−888. https://doi.org/10.3168/jds.2017-13191

Izanloo A., Condon A.G., Langridge P., Tester M., Schnurbusch T., 2008. Different mechanisms of adaptation to cyclic water stress in two South Australian bread wheat cultivars. J. Exper. Botan. 59(12), 3327−3346. https://doi.org/10.1093/jxb/ern199

Jilani M., Ajam Norouzi H., Faraji A., 2018. Effect of bed planting on the quantity and quality of hay in different mixing ratios of vetch and barley in the north of Iran. Appl. Ecol. Envir. 16(4), 4477−4490. http://dx.doi.org/10.15666/aeer/1604_44774490

Klevenhusen F., Zebeli Q., 2020. A review on the potentials of using feeds rich in water-soluble carbohydrates to enhance rumen health and sustainability of dairy cattle production. J. Sci. Food. Agric. 101(14), 5737−5746. https://doi.org/10.1002/jsfa.11358

König W., Lamminen M., Weiss K., Tuomivirta T.T., Sanz Muňoz S., Fritze H., Elo K., Puhakka L., Vanhatalo A., Jaakkola S., 2017. The effect of additives on the quality of white lupin–wheat silage assessed by fermentation pattern and qPCR quantification of clostridia. Grass Forage Sci. 72(4), 757−771. https://doi.org/10.1111/gfs.12276

Litwińczuk Z., Żółkiewski P., Chabuz W., Florek M., 2013. Przyrosty dobowe i wartość rzeźna buhajków opasanych paszami z trwałych użytków zielonych i kiszonką z kukurydzy z uwzględnieniem wartości pokarmowej skarmianych pasz. Rocz. Nauk. Pol. Tow. Zootech. 9(4), 27−35.

Mustafa A.F., Seguin P., 2004. Chemical composition and in vitro digestibility of whole-crop pea and pea–cereal mixture silages grown in South-western Quebec. J. Agron. Crop Sci. 190(6), 416−421. https://doi.org/10.1111/j.1439-037X.2004.00123.x

Marković J., Vasić T., Terzić D., Štrbanović R., Knežević J., Blagojević M., Lazarević D., 2020. Protein and carbohydrate fractions of common vetch-oat mixtures depending on stage of growth and seeding rate in the mixtures. Emir. J. Food Agric. 32(12), 890−896. https://doi.org/10.9755/ejfa.2020.v32.i12.2223

Maxin G., Andueza D., Le Morvan A., Baumont R., 2017. Effect of intercropping vetch (*Vicia sativa* L.), field pea (*Pisum sativum* L.) and triticale (*X Triticosecale*) on dry-matter yield, nutritive and ensiling characteristics when harvested at two growth stages. Grass Forage Sci. 72(4), 777−784. https://doi.org/10.1111/gfs.12277

Nazarli H., Faraji F., 2011. Response of proline, soluble sugars and antioxidant enzymes in wheat (*Triticum aestivum* L.) to different irrigation regimes in greenhouse condition. Cercet. Agron. Moldova 4, 27−33. https://doi.org/10.2478/V10298-012-0046-1

Oba M., 2010. Effects of feeding sugars on productivity of lactating dairy cows. Can. J. Anim. Sci. 91(1), 37−46. https://doi.org/10.4141/CJAS10069

Ondarza M.B., Emanuele S.M., Sniffen C.J., 2020. Dietary sugars for optimizing rumen function and dairy cow performance. Virtual Corn. Nutrit. Conf., October 2020.

Omokanye A.T., Lardner H., Lekshmi S., Jeffrey L., 2019. Forage production, economic performance indicators and beef cattle nutritional suitability of multispecies annual crop mixtures in northwestern Alberta, Canada. J. Appl. Anim. Res. 47(1), 303–313. https://doi.org/10.1080/09712119.2019.1631830

PN-EN ISO 12099:2010. Pasze, ziarna zbóż, produkty przemiału. Wytyczne stosowania spektrometrii bliskiej podczerwieni. PKN, Warszawa.

Rad S.V., Valadabadi S.A.R., Pouryousef M., Saifzadeh S., Zakrin H.R., Mastinu A., 2020. Quantitative and qualitative evaluation of *Sorghum bicolor* L. under intercropping with legumes and different weed control methods. Horticulturae 6(4), 78. https://doi.org/10.3390/horticulturae 6040078

Salama H.S.A., 2020. Mixture cropping of berseem clover with cereals to improve forage yield and quality under irrigated conditions of the Mediterranean Basin. Ann. Agric. Sci. 65(2), 159–167. https://doi.org/10.1016/j.aoas.2020.09.001

Taweel H.Z., Tas B.M., Smit H.J., Elgersma A., Dijkstra J., Tamminga S., 2005. Effects of feeding perennial ryegrass with an elevated concentration of water-soluble carbohydrates on intake, rumen function and performance of dairy cows. Anim. Feed Sci. Technol. 121(3–4), 243–256. https://doi.org/10.1016/j.anifeedsci.2005.02.024

The source of funding: Ministry of Science and Higher Education, grant no 30/20/B.

Received: 12.01.2022
Accepted: 04.04.2022