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Review article

NUTRITIVE VALUE OF FIELD PEA – OAT AND COMMON VETCH – OAT BICROPS

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Abstract: Peas and vetches are the most important plant species for the production of forages, where they can be used as hay, haylage or silage. Due to their specific characteristics – tendency to lodging and high buffering capacity, they are usually grown in a mixture with small grains as support crops to prevent or reduce lodging, reduce buffering capacity, and at the same time obtain biomass suitable for the ensiling process. In pure crops, peas are most often used as green feeds or hay at the stage of first pod formation, while the best quality of vetch dry matter has been achieved by using it at the stage of full flowering or the beginning of first pod formation, when up to 25% of crude protein is obtained in the biomass of pure culture. The nutritive value of pure crops of peas, common vetch and oats, and their mixtures is presented as a function of the structure of the mixtures and the stage of use. Special attention is paid to the content of cell wall components and the dry matter digestibility of these feeds. Because of all of these mentioned above, it is particularly important to choose the right harvesting time to balance the yield and nutritional value of feeds used in bicrops.

Key words: pea – oat mixture, comon vetch – oat mixtures, nutritive value.

Introduction

Modern livestock production implies intensive breeding of specific domestic animal species selected for high genetic potential of animal production. The high price of the concentrated feeds indicates the fact that the economy of the animal production is primarily reflected in the maximum use of forages, which are significantly cheaper than concentrates. Based on the above, the preservation of annual legumes (peas and vetches) in combination with small grains by ensiling is

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one of the possible solutions for the production of high quality forages for ruminant nutrition.

Advances in dairy farming are primarily the result of significant advances in nutrition practice. The greatest progress has been made through the application of a continuous diet of preserved forages throughout the year (Radivojević et al., 2015). Alfalfa and corn are the main forage crops in Serbia and the Balkan region. However, climatic conditions during the summer season are less optimal for corn production, and high summer temperatures contribute to the production of corn silage with a higher lignin content, which is characterized by lower digestibility. There are few forage crops that can completely replace corn silage in the diet of dairy cattle. However, the solution to this problem is the silage of annual legumes grown in the bi – cropping system with small grains (Radivojević et al., 2015).

The nutritive value of grasses and legumes decreases as the plant matures, primarily due to the lower leaf to stem ratio in mature plants and the very rapid decline in stem quality during plant growth and development. To produce high quality forages, it is necessary to harvest these plants at a stage of development when the leaf to stem ratio is high. However, the chemical composition of annual legumes and cereals does not change in the same way as the chemical composition of grasses and perennial legumes, probably due to the ratio of pods to seeds in the DM (dry matter) (Salawu et al., 2001). Therefore, it is very difficult to determine when to harvest these crops to obtain high quality forages. On the other hand, the chemical composition of annual legumes – field peas and vetches – does not change as much as the chemical composition of cereals, so the harvesting time of these plants grown in bi – crop systems depends largely on the developmental stage of cereals (Salawu et al., 2001; Marković et al., 2019a, b).

Barley, oats and wheat are the cereals most commonly used in the bi – crop systems with leguminous plants (Chapko et al., 1991; Salawu et al., 2001). The type of cereals used in the bi – crop systems greatly affects the nutritive value and DM yield, but it should be noted that barley and oats have some advantages over the other cereals (Khorasani et al., 1993). Some authors (Chapko et al., 1991; Salawu et al., 2001) indicated that growing field peas in a bi – crop with wheat, oats and barley leads to an increase in CP (crude protein) content and a decrease in NDF (neutral detergent fiber) and ADF (acid detergent fiber) content compared to cereals grown in monoculture. Mustafa and Seguin (2004) also found that field pea silage is characterized by a higher CP content and lower NDF and ADF contents in relation to pea – cereal silages.

The importance of pea and vetch cultivation in bi – crop with oats

Annual legumes are mostly grown as monocultures, but in some countries intercropping with cereals is a common practice (Klimek-Kopyra et al., 2014).

Field peas and vetches are important plant species for the production of forages used as hay, haylage or silage (Dinić et al., 2008, 2011). Due to their characteristics (tendency to lodge down and high buffer capacity), they are most often grown in a mixture with small grains as supporting crops to prevent or reduce lodging, reduce buffer capacity, and also produce biomass suitable for ensiling process (Đorđević et al., 2010; Blagojević et al., 2014; 2015a, b; 2017). In pure crops, peas are most often used as hay when the first pods are formed, whereas the best quality of common vetch is achieved by using it at full flowering or when the first pods start to form (Karagić et al., 2011a).

Field pea (*Pisum sativum* L.) is an exceptional plant species for animal nutrition, both from the point of view of its use as a cereal and as animal feed. Compared to other legumes of similar quality and uses, peas have much more modest requirements for growing conditions. Pea is also a species that easily lodges down, so it is sown in a mixture with cereals as supporting crops (Omokanye, 2014). As a pure crop, for green forage and hay, it is used at the stage of first pod formation. The herbage yield of peas varies depending on the variety, fertilization, harvest period and cultivation method. Ensiling is the best solution to preserve the nutritional value of pea herbage, until the time of use (Kwabiah, 2004).

Common vetch (*Vicia sativa* L.) is used for feeding animals in the form of green forage and hay, but also as silage (Karagić et al., 2011b; 2012). It is rarely sown as a pure crop, and due to its pronounced tendency to lodge down, it is most often grown in a mixture with small grains – mainly oats and rye, which increases the total herbage and dry matter yield as well as the nutritional value (Seven and Cerci, 2006). The best dry matter quality of vetches is achieved when they are harvested at the full flowering stage or at the formation of the first pods, when the dry matter contains from 18.6 to 22.6% crude protein (Caballero et al, 1995).

Green forage and dry matter yields of pea – oat and common vetch – oat mixtures

When legumes are grown in a bi – crop system with small grains, the choice of leguminous species has a significant impact on forage yield and quality (Altin and Ucan, 1996). Furthermore, several factors influence forage yield in a mixed crop, including the variety, the proportion of seeds in the mixture, and the qualitative properties of the components in the mixture (Caballero et al., 1995; Carr et al., 2004; Drooshiotis, 1989). Numerous authors have noted that combining annual legumes and small grain crops results in higher yields and a more balanced nutrient ratio (Haymes and Lee, 1994; 1999; Anil et al., 1998; Carr et al. 2004).

The yield of DM and the content of CP in combined crops are primarily influenced by the proportion of the individual components in the mixture. The proportion of leguminous seeds in the mixture (peas and vetches) can affect the CP content of the forage obtained, but has no effect on DM yields in combined crops of annual legumes and grains (Carr et al., 1998). The proportion of cereal seeds in the mixture, on the other hand, significantly affects DM yields.

According to Ericson and Norgren (2003), the DM yield of peas grown in a monoculture ranged from 3.5 to 6 t ha^{-1}, whereas the DM yield of a combined crop of peas and oats ranged from 4.7 to 6.8 t ha^{-1} when the proportion of pea seeds in the mixture was 330 to 460 g kg^{-1}. Åman and Graham (1987) found comparable pea DM yields ranging from 3.8 to 6.5 t ha^{-1}. Fraser et al. (2001) indicated that the pea DM yield was comparable at various stages of development, primarily due to an increase in the plant DM as the plant grows and develops.

Bayram and Celik (1999) indicated that the highest DM yield of 10.46 t ha^{-1} was found in a mixture of 25% vetches and 75% oats, while the DM yield of a pure vetch crop was 9.65 t ha^{-1}. Caballero et al. (1995) found that a combined vetch – oat bi – crop produced 34% more DM than a pure vetch crop, but 57% less than a pure oat crop. Basbag et al. (1999) determined that the proportion of small grains in the mixture increased the forage yield of combined crops, and that the highest DM yield of 7.6 t ha^{-1} was established in a 50:50 mix of vetches and barley. Konak et al. (1997) reported that forage yield of a vetch – oat mixture was 41.14 t ha^{-1}, and DM yield was 11.18 t ha^{-1}. According to Tuna and Orak (2002), the highest herbage yield (29.0 t ha^{-1}) was established in a mixture containing 25% vetches and 75% oats, and the lowest forage yield in a pure crop of vetches (17.8 t ha^{-1}). The same authors indicated that the mixture containing 75% vetches and 25% oats produced the lowest forage yield (15.6 t ha^{-1}), but the highest DM yield was obtained in the pure oat crop (7.2 t ha^{-1}) and the lowest in the mixture with 75% vetches (5.0 t ha^{-1}). Similar results were found by Altin and Ucan (1996), Bayram and Celik (1999), Basbag et al. (1999), Tansi et al. (1993).

The data on forage and DM yield in the study conducted by Marković et al. (2018a) presented in Tables 1 and 2 show statistically significant differences among the treatment means.

Table 1. The effect of vetch + oat pure stands and their mixtures on green forage yield (t ha^{-1}) at different growth stages.

Mixture rate oat:vetch (%)	Growth stage I	Growth stage II	Growth stage III	Means
Pure oat	59.7^{a}	49.9^{a}	49.0^{a}	52.86^{A}
60:40	55.2^{b}	46.6^{b}	38.7^{b}	46.83^{B}
50:50	46.5^{c}	44.1^{b}	33.0^{c}	41.20^{C}
40:60	38.6^{d}	34.5^{c}	29.5^{d}	34.20^{D}
Pure vetch	29.2^{e}	22.8^{d}	20.0^{e}	24.00^{E}
Means	45.84^{A}	39.58^{B}	34.04^{C}	

Different letters denote significantly different means (P< 0.05), Marković et al. (2018a).

The maximum DM yield of 14.15 t ha^{-1} was produced by oat monocultures (Table 2), followed by a mixture of 60% oats + 40% vetches (12.48 t ha^{-1}). As the growth stage progressed, the DM yield increased from the beginning of vetch flowering to forming the first pods on 2/3 of the vetch plants. In the pure stand treatments, the highest DM yield of 14.68 t ha^{-1} was produced by oats at the third growth stage, and the lowest by vetches in monoculture (5.81 t ha^{-1}) at the same growth stage.

Table 2. The effect of pure vetch + oat stands and their mixtures on dry matter yield (t ha^{-1}) at different growth stages.

Mixture rate oat:vetch (%)	Growth stage I	Growth stage II	Growth stage III	Means
Pure oat	13.82^{a}	13.97^{a}	14.68^{a}	14.15^{A}
60:40	13.13^{a}	12.81^{b}	11.50^{b}	12.48^{B}
50:50	11.06^{b}	12.12^{b}	9.86^{c}	11.01^{C}
40:60	9.56^{c}	10.60^{c}	9.06^{c}	9.74^{D}
Pure vetch	7.00^{d}	6.21^{d}	5.81^{d}	6.34^{E}
Means	10.91^{A}	11.14^{A}	10.18^{B}	

Different letters denote significantly different means ($P < 0.05$), Marković et al. (2018a).

Nutritive value of pea – oat and common vetch – oat mixtures

It is important to mention that the most significant changes in the chemical composition of pea dry matter occur during the grain filling stage of development (Åman and Graham, 1987). Nutrients, especially CP and carbohydrates, are translocated from the vegetative parts of the plant to the seeds, while cellulose and hemicellulose, as well as lignin are accumulated in the leaf and especially in the stem. In general, during growth and development, the soluble sugars converted to starch and the content of structural carbohydrates are increased (Åman and Graham, 1987).

CP is one of the most expensive components in animal feeds, with a large impact on production costs. Feeding excess CP can result in unnecessary feed expenses with no return in milk or milk protein yield (Blagojević et al., 2017). Jaster et al. (1985) indicated that CP content and soluble protein content decreased with growth and development in the combined crop of peas and oats. In contrast, the dry matter content, starch and NDF of peas increase with the stage of development progress. The content of CP, starch, NDF, ADF and soluble sugars in combined bi – crop systems of peas and oats depends on the plant developmental stage of the individual components, even in bi – crop mixtures, and also on the seed ratio of the individual components in the mixtures (Salawu et al, 2001). Previous research has established that ruminants prefer legumes to grasses, regardless of whether they have comparable DMD (Beever and Throp, 1996; Salawu et al., 2002).

Marković et al. (2017a) investigated the content of CP and protein fractions of pea:oat mixtures at two different mixture rates: 50% peas + 50% oats and 75% peas + 25% oats at three developmental stages: 10% of flowering, forming the first pods on 2/3 of pea plants and forming green seeds in 2/3 of pods. These authors found that the content of CP during plant growth and development ranged from 176.82 to 136.00 g kg^{-1} DM in the 50:50 pea – oat mixture and from 192.58 to 166.80 g kg^{-1} DM of the 75:25 pea – oat mixture, respectively. The same authors also indicated that the average level of CP in the 75:25 pea – oat mixture was 20.59 g kg^{-1} DM higher than in the 50:50 pea – oat mixture, due to the higher quantity of peas in this mixture.

Table 3. The crude protein content and fraction distribution determined according to the Cornell Net Carbohydrate and Protein System (CNCPS).

		CP g kg^{-1} DM	PA g kg^{-1} CP	PB_1 g kg^{-1} CP	PB_2 g kg^{-1} CP	PB_3 g kg^{-1} CP	PC g kg^{-1} CP
R_1	P_1	176.82^b	473.70^e	79.72^a	279.06^c	82.87^a	84.65^d
	P_2	152.58^d	549.85^b	17.98^d	276.02^d	52.50^c	103.65^a
	P_3	136.00^e	500.60^d	11.97^e	375.60^a	15.23^f	96.60^b
R_2	P_1	192.58^a	535.55^c	9.78^e	350.37^b	37.65^d	66.65^f
	P_2	167.06^c	559.70^a	33.10^c	267.05^e	63.75^b	76.40^e
	P_3	166.80^c	459.80^f	51.20^b	374.85^a	20.65^e	93.50^c
Average R_1		155.13^b	508.05^b	36.55^a	310.23^b	50.20^a	94.97^a
Average R_2		175.72^a	518.35^a	31.37^b	330.76^a	40.67^b	78.85^b
Average P_1		184.85^a	504.63^b	44.75^a	314.74^b	60.23^a	75.65^c
Average P_2		160.03^b	554.78^a	25.54^c	271.53^c	58.12^b	90.03^b
Average P_3		151.45^c	480.20^c	31.58^b	375.22^a	17.95^c	95.05^a

R_1 – first mixture, 50% peas + 50% oats; R_2 – second mixture, 75% peas + 25% oats; P_1 – a cutting of the biomass at the start of pea flowering (10% of flowering); P_2 – a cutting of biomass at forming the first pods on 2/3 of pea plants; P_3 – a cutting of biomass at forming of green seeds in 2/3 of pods; CP – crude protein, PA – non-protein nitrogen; PB_1 – the rapidly degraded crude protein; PB_2 – the intermediately degraded crude protein; PB_3 – the slowly degraded crude protein; PC – the bound crude protein; Different letters denote significantly different means ($P< 0.05$), Marković et al. (2017a).

An analysis of variance found statistically significant differences among mixtures for CP content in the study conducted by Marković et al. (2017b). In this study, peas and oats were tested at five different mixture rates: 100% peas, 100% oats, 25% peas + 75% oats, 50% peas + 50% oats and 75% peas + 25% oats at first pod formation on 2/3 of the pea plants. The highest CP content was observed in the plots of 100% peas, and the lowest CP content was obtained in the plots of 100% oats. Among the mixtures, the highest CP content was found in the 75% pea mixture. These authors concluded that the CP content increased with increasing pea content in the mixtures due to the high CP content in peas.

In ruminant nutrition, a balance between structural and non – structural carbohydrates and proteins is very important to reduce nutrient losses, such as nitrogen, which is very important in a sustainable production system (Marković et al., 2020a, b). Carbohydrates are important in animal nutrition, because they are the main source of energy and usually make up 70 – 80% of the diet. Cell walls are the main fraction of carbohydrates and play an important role in both plant and animal nutrition. They provide structural support and protection to plants. These functions mean that these components are resistant to degradation, which limits the use of nutrients in animals. In fact, animals do not produce the enzymes needed to digest cell walls, but they have developed beneficial relationships with microorganisms that are able to degrade cell walls.

Table 4. The chemical composition, carbohydrate fractions, and digestibility of herbage of different pea – oat mixtures.

	A_1	A_2	A_3	A_4	A_5
DM, g kg^{-1}	248.3^d	280.0^a	271.6^b	263.0^c	270.3^b
CP, g kg^{-1} DM	190.3^a	114.5^e	126.8^d	152.8^c	167.3^b
CHO, g kg^{-1} DM	685.3^d	753.6^a	736.2^b	705.6^c	697.4^{cd}
NSC, g kg^{-1} DM	225.7^a	139.5^d	179.8^b	178.8^b	166.6^c
Starch, g kg^{-1} DM	66.7^a	67.7^a	65.2^a	67.4^a	56.5^b
NFC, g kg^{-1} DM	279.1^a	106.5^e	148.5^d	165.2^c	200.4^b
aNDF, g kg^{-1} DM	435.9^e	663.8^a	606.2^b	564.2^c	520.4^d
ADF, g kg^{-1} DM	352.1^c	441.4^a	443.5^a	415.1^b	417.3^b
HCL, g kg^{-1} DM	76.2^e	203.4^a	149.1^b	136.4^c	93.2^d
Lignin, g kg^{-1} DM	61.6^b	81.1^a	82.4^a	69.8^b	82.2^a
DMD, g kg^{-1} DM	774.0^a	579.8^e	611.4^d	649.8^c	691.1^b
CA, g kg^{-1} CHO	329.4^a	185.2^d	244.3^c	253.4^b	238.9^c
CB_1, g kg^{-1} CHO	97.4^a	89.8^b	88.6^b	95.5^a	81.1^c
CB_2, g kg^{-1} CHO	166.8^a	77.9^d	79.2^d	110.7^c	147.9^b
CB_3, g kg^{-1} CHO	258.4^e	452.3^a	389.5^b	372.9^c	334.7^d
CC, g kg^{-1} CHO	148.0^b	194.7^a	197.9^a	167.4^b	197.2^a

A_1 – 100% peas + 0% oats; A_2 – 0% peas + 100% oats; A_3 – 25% peas + 75% oats; A_4 – 50% peas + 50% oats; A_5 – 75% peas + 25% oats; DM – dry matter; CP – crude protein; CHO – total carbohydrates; NSC – non-structural carbohydrates; NFC – non-fiber carbohydrates; aNDF – neutral detergent fiber; ADF – acid detergent fiber; HCL – hemicellulose; DMD – dry matter digestibility; CA – instantaneously degradable carbohydrates; CB_1 – starch; CB_2 – intermediately degradable carbohydrates; CB_3 – available cell wall; CC – unavailable cell wall; Different letters in the same row denote significantly different means ($P < 0.05$); Marković et al. (2017b).

In low production grazing ruminants, plant cell walls represent 70–90% of the total carbohydrates ingested by the animals. Because cell walls are digested slowly and incompletely, the ratio of cell walls in the diets of high producing cows must be limited, but they still make up 40–60% of the carbohydrates in the diet. The amount of cell walls in the diet of ruminants and the negative impact on the amount of meals ingested and digested by dairy cows show the importance of studying the structure and utilization of cell walls. Discovering the relationship between the chemical nature of cell walls and their utilization will help us to understand and reduce their limiting factor in the diet of dairy cows and achieve that forages are used more efficiently and in greater quantities (Marković et al., 2019a, b).

Kocer and Albayrak (2012) indicated that the content of NDF and ADF increased with decreasing pea content in the mixture. According to the findings of these authors, pure pea crops contained the lowest content of ADF and NDF – 258.1 and 382.7 g kg^{-1} DM, respectively, whereas the highest content of ADF and NDF was found in pure oat crops (346.1 and 591.2 g kg^{-1} DM, respectively). Aasen et al. (2004) reported that increasing the content of the legume component in mixtures with grasses and cereals contributed to a decrease in the content of NDF and ADF. Van Soest (1996) also pointed out that legumes under similar growing conditions had lower levels of ADF and NDF, whereas cereals contained higher levels. Carr et al. (2004) found lower NDF and ADF levels in the pea – oat mixtures compared to pure oats. These authors also found that growing peas and oats in a bi – crop system contributed to better nutrient digestibility compared to growing oats alone.

Balabanli et al. (2010) studied the content of NDF and ADF in mixtures of common vetch with different cereals – rice, barley, wheat, oats, triticale, and found that the NDF content ranged from 501.1 to 513.9 g kg^{-1} DM and the ADF content ranged from 319.2 to 327.9 g kg^{-1} DM, respectively. Lithourgidis et al. (2006) found that the NDF content increased as the common vetch seed increased in the mixture. In the pure common vetch crop, the NDF content was 443.1 g kg^{-1} DM, while in the pure oat crop the NDF content was 345.3 g kg^{-1} DM. The determined value for the NDF content in the mixture with a ratio of common vetch to oats of 55:45 was 367.7 g kg^{-1} DM, and the NDF content was 401.7 g kg^{-1} DM when the ratio of common vetch to oats was 65:35. These authors found that pure common vetch had the highest NDF content, which is in contrast to the results obtained by Caballero et al. (1995) and Assefa and Ledin (2001). The reason for these results could be that different legume cultivars were used or the legumes were harvested at different stages of development. In the mixture where the ratio of common vetch to oats was 55:45, these authors found 387.0 g kg^{-1} DM of ADF and 55.5 g kg^{-1} DM of lignin, while in the mixture where the ratio of common vetch to oats was 65:35, the ADF content was 351.4 g kg^{-1} DM, while the lignin content was 55.8 g kg^{-1} DM. They found that increasing the proportion of legumes in the mixture increased the lignin content, which can be explained by the fact that the cell walls of cereals contain less lignin compared to the cell walls of legumes (Carpita and McCann, 2000). The same authors found in these studies that the DMD of the pure common vetch crop was 604.0 g kg^{-1} DM, the DMD of the pure oat crop was 602.7 g kg^{-1} DM, while in a mixture where the ratio of common vetch to oats was 55:45, the DMD was 587.5 g kg^{-1} DM, and in the mixture where this ratio was 65:35, the DMD was 615.2 g kg^{-1} DM. Caballero et al. (1995) pointed out that an adequate contribution of common vetch to forage quality can only be achieved if the proportion of oat seeds in the mixture is 10–20%.

Assefa and Ledin (2001) studied the NDF content in different oat varieties, and found that the NDF content ranged from 628 to 661 g kg^{-1} DM, while the IVOMD (*In vitro* Organic Mater Digestibility) ranged from 540 to 589 g kg^{-1} DM. The content of NDF in the leaf was 622 g kg^{-1}, and in the stem 742 g kg^{-1}, while the DMD of the leaf was 613 g kg^{-1} DM and the DMD of the stem was 372 g kg^{-1} DM. These authors found that legumes were characterized by better nutritional value, but lower DM yields per hectare. Nsahlai and Umunna (1996) indicated that the content of CP and NDF in a similar experiment conducted with mixtures of oats and common vetch had a direct influence on the DM intake and DMD of forages.

Legumes contribute to higher levels of nitrogen and other minerals in the rumen, which increases the activity of rumen microorganisms, and thus improves the conditions for better digestion and passage rate of food through the digestive tract (Bonsi et al., 1994). Feeding animals mixtures of legumes and oats will therefore improve the DM intake, passage rate and digestion of food. These observations were confirmed in the study of Abule et al. (1996), who found a better DM intake of a barley – legume mixture. On the other hand, there are a number of factors that influence the fiber requirements of dairy cows, including DM intake, the amount and type of non – structural and structural carbohydrates in the diet, particle size and nutrient processing, and the rate and extent of fiber fermentation processes. A better knowledge of these factors is necessary to achieve maximum energy intake in early lactation. NRC (2001) recommends that the NDF and ADF content of the meal should be 25–28% and 19–21%, respectively, and that 75% of the NDF should come from forages.

Fibers consist of an indigestible fraction and one or more digestible fractions, and each of these fractions has a special rate of degradation. The process of fiber digestion consists of hydrolysis of polysaccharides and conversion of monosaccharides into volatile fatty acids, gases produced during fermentation, and heat (Tamminga, 1993). The degree of hydrolysis depends on how much the enzymes that break down the complex formed between lignin and carbohydrates can penetrate it (Chesson, 1988). The degree of digestion depends on the size of the indigestible fraction and the relationship between the degree of degradability and the passage of the fibers through the rumen into the digestive system. As the digestibility of fiber derived from forages varies depending on the species and category of animals, these variations may be due to differences in the composition of forages, depending on the time of harvest. The indigestible fraction of the NDF is the main factor influencing the utilization of fibrous carbohydrates and can make up more than half of the total NDF in the rumen. Therefore, there must be a balance between the total fibers and the indigestible fiber fractions (Varga et al., 1998).

The results of the study conducted by Marković et al. (2018b) are presented in Table 5. The average values for the NDF content of common vetch at different growth stages showed that the NDF content increased from flowering (568.7 g kg^{-1} DM) to the stage of first pod formation (583.6 g kg^{-1} DM), but did not differ significantly.

Table 5. The forage quality of intercropped common vetch (*Vicia sativa* L.) and oats (*Avena sativa* L.).

Factors A	Factors B	DMY t ha^{-1}	CP g kg^{-1} DM	CPY kg ha^{-1}	ADF g kg^{-1} DM	NDF g kg^{-1} DM	Lignin g kg^{-1} DM	DMD g kg^{-1} DM
a_1	b_1	7.00^{h}	183.7^{c}	1285.9^{j}	440.4^{b}	509.2^{g}	88.0^{d}	649.9^{b}
	b_2	13.82^{b}	99.5^{i}	1375.1^{h}	404.5^{e}	627.0^{b}	61.3^{b}	589.7^{d}
	b_3	13.13^{c}	125.3^{g}	1645.2^{ab}	432.9^{c}	575.8^{d}	75.8^{g}	619.2^{c}
	b_4	11.06^{ef}	147.2^{e}	1628.0^{b}	415.0^{d}	562.2^{d}	74.8^{g}	620.9^{c}
	b_5	9.56^{g}	155.3^{d}	1484.7^{f}	441.0^{b}	569.2^{d}	86.5^{e}	628.6^{c}
Average A_1		10.91	142.2	1551.4	426.8	568.7	77.3	621.6
a_2	b_1	6.21^{i}	213.4^{a}	1325.2^{i}	434.0^{c}	527.7^{f}	96.9^{b}	656.7^{a}
	b_2	13.97^{b}	114.5^{b}	1599.5^{c}	441.4^{b}	663.8^{a}	81.1^{f}	579.8^{d}
	b_3	12.81^{cd}	121.6^{g}	1557.7^{d}	448.9^{a}	597.0^{c}	91.1^{c}	567.3^{e}
	b_4	12.12^{d}	124.3^{f}	1627.7^{b}	413.8^{d}	569.9^{d}	85.2^{e}	574.7^{e}
	b_5	10.60^{f}	157.6^{d}	1670.5^{a}	419.5^{d}	559.5^{e}	88.3^{d}	566.5^{e}
Average A_2		11.14	148.3	1652.0	431.5	583.6	88.5	589.0
a_3	b_1	5.81^{j}	200.1^{b}	1162.5^{k}	428.0^{c}	520.1^{f}	100.8^{a}	638.6^{b}
	b_2	14.68^{a}	97.0^{i}	1423.9^{g}	396.6^{f}	578.8^{d}	89.9^{d}	536.1^{g}
	b_3	11.50^{e}	130.9^{f}	1505.3^{e}	397.1^{f}	548.0^{e}	90.9^{c}	565.4^{e}
	b_4	9.86^{g}	141.6^{e}	1396.2^{h}	399.2^{f}	551.5^{e}	95.1^{b}	552.2^{f}
	b_5	9.06^{g}	145.5^{e}	1318.2^{i}	401.2^{e}	551.9^{e}	93.4^{c}	574.4^{e}
Average A_3		10.18	143.0	1455.7	404.4	550.1	94.0	573.3
Average B_1		6.34	199.1	1262.3	454.2	519.0	95.2	648.3
Average B_2		14.15	103.7	1467.4	414.2	623.2	77.4	548.5
Average B_3		12.48	125.9	1571.2	426.3	573.6	85.9	584.0
Average B_4		11.01	141.0	1552.4	409.4	561.2	85.0	582.6
Average B_5		9.74	152.8	1488.3	420.6	560.2	89.4	589.8

A – growth stage; B – mixture rate; DMY – dry matter yield; CP – crude protein; CPY – crude protein yield; ADF – acid detergent fiber; NDF – neutral detergent fiber; DMD – dry matter digestibility; a_1 – vetch flowering initiation – 10% of flowering; a_2 – forming the first pods on 2/3 of vetch plants and a_3 – forming green seeds in 2/3 of pods; b_1 – 100% vetches + 0% oats; b_2 – 0% vetches + 100% oats; b_3 – 40% vetches + 60% oats; b_4 – 50% vetches + 50% oats and b_5 – 60% vetches + 40% oats; Different letters in the same column denote significantly different means ($P< 0.05$), Marković et al. (2018b).

As growth and development continued, the NDF content decreased by 5.75% (Table 5). The lowest NDF content was found in pure vetches (519.0 g kg^{-1} DM), while the highest NDF content was found in pure oats (623.2 g kg^{-1} DM). The highest lignin content was found in pure common vetch (95.2 g kg^{-1} DM). According to the fact that common vetch contained a significantly higher lignin content, the mixture with the highest proportion of common vetch contained the highest lignin content (89.4 g kg^{-1} DM). The dry matter digestibility of the vetch – oat mixtures studied decreased by 8.42% with growth and development. Pure common vetch was 14% more digestible than pure oats, whereas the common vetch seeding rate did not contribute to the better digestibility of vetch – oat mixtures.

Early lactating cows fed diets containing more digestible fibers consumed 1.18 kg more DM and produced 1.23 kg more milk per day than cows fed diets containing less digestible fibers. The NDF concentration in the ration is negatively correlated with the DM intake because the fibers ferment more slowly and remain longer in the rumen compared to other nutrient components (Varga et al., 1998). Allen and Oba (1986) reported that a 1– unit increase in digestion led to a higher milk production of 0.23 kg per day.

Aasen et al. (2004) reported that increasing the seeding rate of leguminous components in the mixtures with grasses and cereals contributed to the reduction of NDF and ADF content. Lithourgidis et al. (2006) also found that NDF content increased with an increase in the proportion of germinated common vetch in the mixtures. Carpita and McCann (2000) found that the lignin content increased with increasing the seeding rate of common vetch in the mixtures, which could be explained by the fact that the cell wall of cereals contains less lignin compared to the cell wall of legumes.

Digestibility of legume – cereal intercrops

The digestibility of organic matter is one of the most important quality parameters of forage plants (Buxton and Redfearn, 1996). Nutritive value changes during plant growth and development, primarily due to a decrease in the leaf to stem ratio (Lloveras, 2001; Guines et al., 2003). In the leguminous stem, the amount of fiber increases over time, and its fermentation in the rumen is partial and slow, directly limiting the available energy, while the digestibility of leaves is relatively constant and high (Buxton and Redfearn, 1996; Guines et al., 2003). Lignified cell walls have a higher lignin content, which is responsible for the lower digestibility. On the other hand, lignified tissues are necessary to ensure the mechanical resistance of the plants, which practically limits the possibilities to increase the quality of forage plants (Buxton and Redfearn, 1996).

The ability to provide adequate energy levels to high – producing dairy cows is dependent on how precisely the feed composition can be determined. Rumen microorganisms use carbohydrates as energy sources to synthesize microbial protein for their growth, which is important for normal rumen function. Carbohydrates are the main source of energy for animals, necessary for maintenance and milk production. They are also precursors in the synthesis of lactose, fat and protein. Formulation of rations based on NDF content is recommended because of the positive correlation between NDF concentration and rumen capacity and the negative correlation between NDF and energy values of nutrients (Mertens, 1994).

Marković et al. (2018c) found the highest DMD in the pure pea crop (744.9 g kg^{-1} DM) and the lowest in the pure oat crop (562.9 g kg^{-1} DM). The results of this study showed that DMD in mixtures decreased with increasing the pea seeding rate from 25:75 to 50:50 in the pea – oat mixture. Marković et al. (2020b) also indicated that the DMD of pea and oat silages was significantly influenced by the structure of the mixtures and the stage of plant development and that DMD was greatly influenced by ADF and lignin content. The DMD of pea – oat mixtures decreased by 6.4% from the first to the second stage of plant development and by 9.25% up to the third stage of development. The decrease in dry matter digestibility was due to the increase in the amount of structural carbohydrates – NDF and ADF – and intensive lignification of the cell wall as the plant grew and developed. The DMD of the pure pea crop was 32.7% higher than the DMD of the pure oat crop. Due to the higher digestibility of the pea crop, higher digestibility was observed in the mixtures with a higher proportion of peas in the mixtures.

The results obtained in the study conducted by Marković et al. (2018b) showed that the DMD of the examined common vetch – oat mixtures decreased with plant growth and development from 621.6 to 573.3 g kg^{-1} DM. The highest DMD was observed in the first stage of development and was 5.3% higher than in the second stage of development. The lowest DMD was observed in the third stage of development and was 2.7% lower than in the second stage of development. The pure common vetch cultivation was characterized by a 14% higher DMD compared to the pure oat cultivation. In the common vetch – oat mixtures studied, the proportion of common vetch in the mixtures did not contribute significantly to better digestibility.

Conclusion

These results illustrate that CP and cell wall components as well as dry matter digestibility of pea – oat and common vetch – oat mixtures were affected by the growth stage and seeding rate of pea, common vetch and oats in the mixtures. The data obtained from these studies show that pea – oat and common vetch – oat mixtures can be successfully grown for forage production. Growing peas and oats and common vetch and oats in mixtures proved to be beneficial for increasing forage quality. In general, pure oats contained a significantly higher content of cell wall components than pure pea and common vetch crops. The higher proportion of legumes in the mixtures influenced the better nutritive value of feeds investigated. The structure of the mixtures also significantly affected the lignin content. It was also determined that all pea – oat and common vetch – oat mixtures studied can provide high quality forage suitable for high animal production. We recommend harvesting vetch – oat mixtures when the first pods have formed on 2/3 of the vetch plants. Regarding the most favorable mixture depending on the seeding rate of common vetch and oats in the mixtures, we recommend a 1:1 common vetch – oat mixture. On the other hand, 25:50 and 50:50 pea – oat mixtures could be recommended for ruminant feeding.

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HRANLJIVA VREDNOST ZDRUŽENIH USEVA GRAŠKA I OVSA I GRAHORICE I OVSA

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R e z i m e

Grašak i grahorica predstavljaju značajne biljne vrste za proizvodnju kabaste stočne hrane, pri čemu se mogu koristiti kao zelena hrana, zatim u vidu sena ili silaže. Zbog svojih specifičnosti (sklonosti ka poleganju i visokog puferskog kapaciteta) najčešće se gaje u smeši sa strnim žitima, kao potpornim usevima, kako bi se na taj način sprečilo ili umanjilo poleganje, smanjio puferski kapacitet, a ujedno dobila biomasa pogodna za proces siliranja. U čistim usevima grašak se kao zelena hrana ili seno najčešće koristi u fazi formiranja prvih mahuna, dok se najbolji kvalitet suve materije kod grahorice postiže njenim iskorišćavanjem u fazi punog cvetanja ili početka obrazovanja prvih mahuna kada se dobija i do 25% sirovih proteina u biomasi čiste kulture. U ovom radu je prikazana hranljiva vrednost čistih useva graška, grahorice i ovsa, i njihovih smeša u zavisnosti od strukture smeše i faze iskorišćavanja. Posebna pažnja je posvećena sadržaju komponenata ćelijskih zidova i svarljivosti suve materije ovih hraniva. Zbog svega navedenog je od posebne važnosti odabrati pravi momenat kosidbe kako bi se na taj način mogao uskladiti prinos i hranljiva vrednost dobijenih hraniva.

Ključne reči: združeni usev graška i ovsa, združeni usev grahorice i ovsa, hranljiva vrednost.

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