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Jerusalem artichoke (*Helianthus tuberosus*) in rabbit nutrition

Topinambur (*Helianthus tuberosus*) ve výživě králíků

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ABSTRACT

Jerusalem artichoke is crop with the possibility of a wide using. The main nutrient of this plant is a non-starch polysaccharide inulin, which is considered like prebiotic. Young rabbits after weaning lose an immunity obtained from colostrum; are stressed by weaning; pre-moult; the permanent incisors are growing and a starch digestion by an enzyme amylase is not fully developed. The aim of this study was to evaluate the effect of the dietary supplement of dried Jerusalem artichoke tuber and tops (the sources of non-starch saccharide) on growth performance and health status of broiler rabbits after weaning in view of prices and efficiency of feeding mixtures. The test was realized through experiments with a different percentage of Jerusalem artichoke tuber (25%, 10%) and top (30%, 20%, 10%). Every experiment was composed of 2 groups – the control group without a supplement of Jerusalem artichoke and an experimental group with a different percentage of Jerusalem artichoke tuber and top. Experimental animals (1095 HY PLUS broiler rabbits) were weaned at 33 - 35 days of age and were fed by complete granulated feeding mixture ad libitum for the whole feeding period. Statistical analyses were performed by using SAS 9.3 The statistical differences ($P<0.05$) were found in average daily gain (rabbits fed 25% Jerusalem artichoke tubers 42.37±13,96 g/day vs. control 36.42±12.91 g/day) and mortality (rabbits fed 10% Jerusalem artichoke tubers 4.17% vs. control 10.83%; rabbits fed.20% Jerusalem artichoke tops 5.26% vs. control 16.67%).

Keywords: rabbit, growth performance, health status, Jerusalem artichoke, inulin, prebiotics

ABSTRAKT

Topinambur je plodina s možností širokého využití. Hlavní živinou této rostliny je neškrobový polysacharid inulin, který je považován za prebiotikum. Mladí králíci po odstavení ztrácejí imunitu získanou z kolostra, jsou stresováni odstavem; přesrstěním; růstem trvalých řezáků, při nevyvinutém štěpení škrobu enzymem amylázou. Cílem této studie bylo zhodnotit vliv doplňku krmiva sušených hlíz a natě topinamburu (zdroje neškrobového sacharidu) na růstovou schopnost a zdravotní stav brojlerových králíků po odstavu, včetně cenové kalkulace. Test byl realizován pomocí experimentů s různým procentem hlíz topinamburu (25%, 10%) a natě (30%, 20%, 10%). Každý experiment byl složen ze 2 skupin – kontrolní skupina bez přídavku topinamburu a experimentální skupina s různým procentem hlíz topinamburu a natě. Pokusná zvířata (1095 HY PLUS brojlerových králíků) byla odstavena ve věku 33 - 35 dnů a byla krmena kompletní granulovanou krmnou směsí ad libitum po celou dobu krmení. Statistické analýzy byly provedeny pomocí SAS 9.3 Statistické rozdíly ($P<0,05$) byly zjištěny v průměrném denním přírůstku (králíci krmení 25% hlízami topinamburu 42,37±13,96 g/den vs. kontrola 36,42±12,91 g/ den) a mortalitě (králíci krmení 10% hlíz topinamburu 4,17% vs. kontrola 10,83%; krmení králíků.20% topinambur topinambur 5,26% vs. kontrola 16,67%).

Klíčová slova: králík, růstová výkonnost, zdravotní stav, topinambur, inulin, prebiotika

INTRODUCTION

The most exacting life period of growing rabbits is the weaning period (21 – 42 days), where the transition from doe´s milk to a solid feed takes place and rabbit digestive system is not completely developed (Gallois et al., 2005). Primarily, amylase and disaccharidase activities remaining low during the period from 25 to 35 days of age (Blas et al., 1994; Gutiérrez et al., 2002; Debray et al., 2003). Consequently, an incomplete intestinal digestion of starch could alter microbial activity as a result of an overflow of readily available carbohydrates in the young rabbit caecum and lead to digestive troubles (Scapinello et al., 1999, Blas and Gidenne, 1998). The dietary starch level is generally in negative correlation with the fibre level. Dietary fibre, especially neutral detergent fibre (NDF), affects the rate of passage of digesta and optimizes caecal fermentation in rabbits (Gutiérrez et al., 2002; Gidenne et al., 2010; Gómez-Conde et al., 2009). Gidenne (2003) described, that cellulose and lignin (poorly digested part of fibre) play a key role in reducing the incidence of diarrhoea in growing rabbits. Fibre sources rich in digestible fibre can replace sources of starch or protein and they improve the digestive health of animal, if a correct supply in lignocellulose is respected. Therefore, the suitable source of carbohydrates is substantial for the health of young rabbits.

Jerusalem artichoke (*Helianthus tuberosus*) contains 11–20% carbohydrates and 70-90% of theses carbohydrates are inulin and inulids (Szambelan et al., 2004). Inulin is a polydisperse non-starch polysaccharide naturally occurring as a storage carbohydrate in some 36.000 plant species. It consists of chains of fructose units coupled by β (2, 1)-bonds most often (though not always) terminated by a single glucose moiety. The degree of polymerization of inulin ranges from 2 to 60 and above depends mainly on the type of plant from which is isolated (Öztürk, 2008; Boeckner et al., 2001; Roberfroid, 1999). Inulin-type fructans (fructo-oligosaccharide, FOS) are soluble dietary fibres, which can be used as prebiotics (Bónai et al., 2010). Prebiotics was defined as a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or limited number of bacteria in the colon and thus improves host health (Gibson and Roberfroid, 1995). Inulin is little digested by humans (Kays and Kultur, 2005), because it is resistant to enzymatic hydrolysis in the upper gastrointestinal tract of monogastric species. It is fermented by colonic microflora, which stimulates the growth of lactobacillus and bifidobacterial cultures especially. Cieślik et al. (2011) underlined the high value of proteins and balanced amino acids composition of Jerusalem artichoke too. The average nutritive values of tubers are 80% of water, 15% of carbohydrate, and 1 – 2% protein. Žaldarienė et al. (2012), described that the tubers of three Jerusalem artichoke varieties contained from 19.26 to 23.21% dry matter (DM). The content of crude protein, crude fibre and crude ash were 5.12 – 7.79% DM; 3.49 – 4.28% DM and 4.58 – 6.75% DM, respectively. Cieślik et al (2011) presented higher values of DM (24.17%) and described the protein content 6.36% DM in Jerusalem artichoke tuber. In general, protein concentration increased with increasing maturity and the higher content of protein may be due to translocation of nitrogen from leaves and stem to tubers later in the season (Cieślik et al., 2011).

Because of the suitable nutrient composition of Jerusalem artichoke and the prebiotic character of inulin, it could be good ingredient of rabbit diets from the view of the digestion and health status of growing rabbits. According to Samanta et al. (2013), dietary oligosaccharides, such as an inulin and oligofructose, are possible substitutes for antibiotics and can improve the gut health and reduce the mortality of rabbits. There are no studies focused on the incorporation of Jerusalem artichoke to the feed mixture of growing rabbits. Therefore, the aim of this study was to find out the appropriate ratio of Jerusalem artichoke tubers and tops in the diet and to evaluate the effect of these supplements on growth performance and health status of broiler rabbits after weaning. Jerusalem artichoke tubers and tops of this crop have universal values of a chemical composition and their prices are different too.

MATERIALS AND METHODS

Experimental animals

The animals studied (n = 1095) were HY PLUS broiler rabbits weaned at 35 days of age. The experiments took place in commercial farms with standard conditions. The environmental conditions were controlled by an automatic heating system (16 – 18 °C), and the light: dark cycle was 12h:12h. Rabbits were kept in all-wire cages, two per cage. The experiments were realised in primary producers and test station with standard conditions which are necessary to take biological experiments.

Diets and water were available *ad libitum*. Feed consumption per group was measured for the whole experimental period therefore statistical evaluation was not possible. Animals were individually weighted at the beginning and in the end of every experiment. Rabbit mortality was noted during experiments.

Experimental complete diets

A control diets were formulated without any supplementation. Table 1 shows the average values of ingredients and chemical composition of control diets formulated for the 5 experiments and the values of 5 experimental diets. The diets 1 and 2 were supplemented with Jerusalem artichoke tubers in amount 25% and 10%, respectively. The diets 3, 4 and 5 were supplemented with Jerusalem artichoke tops in amount 30%, 20% and 10%, respectively. Because of the diets development every experiment was finished at the different age of rabbits and was repeated. Experiment with 25% artichoke tubers lasted only 21 days, because this post-weaning period is the most exacting period for rabbits and artichoke tubers are relatively expensive. This experiment was realized in the five repeating. Experiment with 10% artichoke tubers (3 repeating), with 20% artichoke tops (3 repeating) and with 30% artichoke tops (4 repeating) lasted 49 days. Experiment with 10% artichoke tops lasted 56 days and it was not repeated. Nutritional composition of all complete diets was relevant with nutrient requirements of rabbits (Zeman et al. 2005).

Instrumental analysis

Feed samples were air dried at 103 °C to constant weight to estimate the dry matter content. Crude protein content was determined by means of watersteam rapid distillation system Vapodest 20s (Gerhardt, Germany). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the procedure of Van Soest et al. (1991), using a Fibertec 1020 (Foss, Denmark). Starch was measured polarimetrically, simple carbohydrates by means of the titration according to Luff-Schoorl.

Statistical methods

Data on growth performance and feed consumption were examined by t-test procedure of SAS 9.3. Data on mortality were analysed using the chi-square test. Means are displayed with standard deviations.

RESULTS

Significantly higher weight gain values were observed in rabbits fed with feed mixture supplemented by 25% Jerusalem artichoke tubers ($P<0.05$) on average by 5.95 g in comparison with control group (Table 2). It was noted, that the moderate increasing of these values in rabbits fed with 30% Jerusalem artichoke tops too (1.24 g) (Table 4) but other groups (10% tubers, 20% and 10% tops) showed the moderate decreasing of rabbit weight gain in comparison with control group by 0.92 g, 1.14 g and 0.62 g on average, respectively (Table 3, 5 and 6). These differences were not statistically significant.

Table 1. Ingredients and chemical composition of experimental diets (g/kg)

	Experimental diets					
	Control	1	2	3	4	5
Ingredients (%)						
Dried Artichoke tops	-	-	-	30	20	10
Dried Artichoke tubers	-	25	10	-	-	-
Alfalfa meal	250	190	200	250	203	250
Wheat bran	180	180	140	100	150	100
Sunflower meal	-	-	-	70	-	65
Soybean meal	30	50	50	-	30	-
Linseed	-	-	-	-	-	20
Sugar beet pulp	70	70	70	100	80	-
Apple pomace	150	140	120	140	97	-
Barley	50	50	50	-	50	-
Oat	50	-	50	-	50	30
Malt sprouts	50	5	5	-	12	10
Whey powder	-	-	-	-	-	10
Probiostan[1]	-	-	-	-	-	-
Lapilest R[2]	150	-	150	-	-	-
Minerals and vitamins	20	20	20	30	20	55
Chemical composition (g/kg)						
Dry matter	905	919	910	872	893	913
Crude protein	144	142	146	136	132	108
Crude fibre	168	132	158	179	162	176
Starch	148	88	135	113	132	184
Simple carbohydrates and inulin	47	169	99	66	57	46
Neutral detergent fibre (NDF)	342	298	302	302	302	326
Acid detergent fibre (ADF)	217	185	181	181	181	185

[1] fermented feed supplement enriched with yeast cells, Lactobacilli and other microorganisms

[2] grape pomace, cocoa peels, buckwheat peels (crude protein 12%, crude fibre 24%, fat 5.5%, starch 2.1%, carbohydrates 2.65%)

Table 2. Influence of feed mixtures (control vs. 25% Jerusalem artichoke tubers) on zootechnical parameters and mortality of rabbits

Parameter	Feed I [1)] Mean±SD n = 178	Feed II [2)] Mean±SD n = 173
Average daily weight gain (g/day)	36.42[b]±12.91	42.37[a]±13,96
Average feed intake (g/day)	114.08±14.07	115.24±16.66
Average feed conversion ratio	3.25±0.53	2.95±0.99
Mortality (%)	6.32	8.94

[1)] control feed, [2)] feed with 25% Jerusalem artichoke tubers
Means with the same subscript in a row differ significantly at the level 0.05

Table 3. Influence of feed mixtures (control vs. 10% Jerusalem artichoke tubers) on zootechnical parameters and mortality of rabbits

Parameter	Feed I [1)] Mean±SD n = 107	Feed II [2)] Mean±SD n = 115
Average daily weight gain (g/day)	36.85±5.18	35.93±5.43
Average feed intake (g/day)	127.8±1.35	119.1±2.10
Average feed conversion ratio	4.23±0.01	4.15±0.35
Mortality (%)	10.83[a]	4.17[b]

[1)] control feed, [2)] feed with 10% Jerusalem artichoke tubers
Means with the same subscript in a row differ significantly at the level 0.05

Table 4. Influence of feed mixtures (control vs. 30% Jerusalem artichoke tops) on zootechnical parameters and mortality of rabbits

Parameter	Feed I [1)] Mean±SD n = 120	Feed II [2)] Mean±SD n = 123
Average daily weight gain (g/day)	35.06±4.83	36.30±4.73
Average feed intake (g/day)	158.3±10.66	157.75±9.84
Average feed conversion ratio	4.03±0.40	3.91±0.51
Mortality (%)	7.69	5.69

[1)] control feed, [2)] feed with 30% Jerusalem artichoke tops
Means with the same subscript in a row differ significantly at the level 0.05

Table 5. Influence of feed mixtures (control vs. 20% Jerusalem artichoke tops) on zootechnical parameters and mortality of rabbits

Parameter	Feed I [1)] Mean±SD n = 100	Feed II [2)] Mean±SD n = 114
Average daily weight gain (g/day)	34.10±9.06	32.96±6.43
Average feed intake (g/day)	138.00±5.51	128.00±5.03
Average feed conversion ratio	4.05±0.21	3.88±0.12
Mortality (%)	16.67[a]	5.26[b]

[1)] control feed, [2)] feed with 20% Jerusalem artichoke tops
Means with the same subscript in a row differ significantly at the level 0.05

Table 6. Influence of feed mixtures (control vs. 10% Jerusalem artichoke tops) on zootechnical parameters and mortality of rabbits

Parameter	Feed I [1)] Mean±SD n = 29	Feed II [2)] Mean±SD n = 36
Average daily weight gain (g/day)	36.75±5.50	36.13±5.15
Average feed intake (g/day)	170.02	160.27
Average feed conversion ratio	4.63	4.43
Mortality (%)	8.11	15.15

[1)] control feed, [2)] feed with 10% Jerusalem artichoke tops
Means with the same subscript in a row differ significantly at the level 0.05

DISCUSION

Feed conversion ratio decreased in all groups with supplement of Jerusalem artichoke. The highest decrease was noted for rabbits fed with 25% Jerusalem artichoke tubers. Yildiz et al (2006) reported that the supplementation of Jerusalem artichoke to laying hen (5% or 10%) improved their feed conversion ratio and they noted that this improving was due to oligofructose or inulin addition. A slight increase in daily gain (about 1.6%) and a decrease in daily feed intake (about 6%) reduced the feed conversion ratio by 0.39 (11%) in the Jerusalem artichoke supplement group compared to the control group. Yildiz et al. (2006) reported that Jerusalem artichoke supplementation to laying hens improved their feed conversion ratio (about 5 – 10%) and noted that this improvement was due to the addition of oligofructose or inulin. These effects were not confirmed by Farnworth et al. (1992) who fed weanling pigs by dose of Jerusalem artichoke at 15 g/kg.

The Jerusalem artichoke supplements in amount of 10% tubers and 20% tops significantly decreased the mortality of rabbits. Decrease of rabbit mortality was noted in animals fed with 30% tops too. However experimental groups fed with 25% Jerusalem artichoke tubers showed higher mortality than control groups. This difference was not statistically significant. It is necessary to emphasize that it was caused by the high rabbit mortality values of one repeating of this experiment. Non-significant decrease of mortality percentage was noted in rabbits fed with mixture supplemented with 10% Jerusalem artichoke tops. Volek et al. (2007) recorded lower mortality of rabbits fed by diet supplemented with inulin, while Bónai et al. (2010) observed no effect of dietary inulin on rabbit mortality (mortality was low in all groups of experiment).

The addition of Jerusalem artichoke (i.e. inulin) to the feeding leads to a metabolic effect similar to addition of antibiotic growth stimulators and anticoccidial additives. Because of feed antibiotics are prohibited in the EU and growth stimulators are significantly limited, these products could theoretically partially replace by oligosaccharide supplements, e.g. inulin. Sakai et al. (2016) also reported a reduction in ulcerative colitis and colorectal cancer following oligofructans and inulin supplementation in human volunteers. This effect of inulin could be caused hypothetically by the increased level of butyrate, which has a protective effect on the intestinal mucosa. Terada (1994) administered to laboratory rats and human volunteer a trisaccharide (galactose, glucose, fructose) and afterwards he noted a significant ($P<0.05$) reduction of *Clostridia perfingens*, staphylococci and other anaerobic bacteria. Furthermore he observed a reduction of undesirable metabolites in the contents of caeca (such as ammonia, phenol, cresol), which led to reduction of odour in the environment. At the same time, protective metabolites (such as acetate and butyrate) were increased.

Feeding of prebiotic is expedient to begin in the early fattering phase of young rabbits and other young animals (piglets, calves, foals), when these young individuals still have access to colostrum/milk from mothers, because they are able to receive by appropriate timing with a slight overlap a prebiotic diet of inulin from Jerusalem artichoke (Mareček and Kvaček, 2009). The using of non-traditional raw materials in the nutrition of rabbits and targeted dietetics during their rearing and fattering. This issue is also elaborated in the article of Kvaček (2011). Non-traditional Jerusalem artichoke crop and its using in feed mixtures for rabbits.

It is necessary to take account of 5 fundamental factors by weaning of young rabbits: their digestion system of starch has not fully developed; they have been weaned (milk feeding have been stopped); they have been experienced to stress from weanling and new socialization; they change their teeth and moult.

Mansourielaheh et al. (2016) published an article about appropriate administration of prebiotics in the form of inulin from Jerusalem artichoke with the aim to increase the number of bifidobacterial in the digestive tract. The feeding of inulin increased the pH in the large intestine and this resulted/related in a subsequent positive reduction in the number of *Escherichia coli*. Terada (1994) administered galactose, glucose and fructose to human volunteers. These results corresponded with our results from observing weaned young farm animals, pets (mainly dogs and cats) and animals kept in ZOOs, e.g. farm animals after weaning perfectly confirmed this theory with their vitality, better immunity and especially lower mortality (Kvaček et al., 2013).

Considerable benefit from studies and feeding trials with Jerusalem artichoke were observed by zoos, namely black rhinos, which have similar type physiology of fibre digestion like rabbits (Skřivanová et al., 2008) or horses (Olehlová., 2018), when the mainly degradation of fibre takes place in the cecum, where the fibre is microbiologically metabolized and, in this way, to create energy e. g. for growth. Degradation of cellulose, fructans, pectin, hemicelluloses would not be possible without symbiotic activity of intestinal bacteria. The breakdown products are volatile fatty acids (VFAs): acetic, propionic, butyric, valeric and caproic, which cover up to 40% of rabbit's basic energy needs from metabolism after resorption into the blood (Carabano et al., 2006).

The favourable effect of Jerusalem artichokes was also observed in a herd of giraffes (*Giraffa reticulata*; *Giraffa Camelopardalis rothschildi*), which gained, had quality fur and good reproduction indicators and maintenance (Kvaček and Vacek, 2011). The similar effect was observed in herds of great black-faced drill monkeys (*Mandrillus leucophaeus*), Nubian antelopes addax (*Addax nasomaculatus*), Oryx, Common eland (T*aurotragus oryx*), Sable antelope (*Hippotragus niger*) and Aardvark (*Orycteropus afer*) too (Vágner, 1990).

CONCLUSION

In conclusion, Jerusalem artichoke supplement improved the zootechnical parameters of young rabbits with the best results in rabbits fed with mixture supplemented with 25% tubers. It seems from results of this study that Jerusalem artichoke tubers and tops supplemented in certain amount improve health status of young rabbits. Therefore, Jerusalem artichoke could be the convenient source of carbohydrates and prebiotic for young rabbits, but it is necessary to make more experiments with this plant in rabbits to the confirmation of these results. This study showed that the rabbit diet supplementation with Jerusalem artichoke (tuber or tops) had small or no effect on the rabbit performance, but reduced the mortality of rabbits after weaning. Feeding mixtures supplemented with Jerusalem artichoke were accepted by rabbits without problems for the whole fattening period.

REFERENCES

Blas, E., Cervera, C., Fernadez-Carmona, J. (1994) Effect of two diets with varied starch and fibre levels on the performances of 4-7 weeks old rabbits. World Rabbit Science, 2, 117–121. DOI: https://doi.org/10.4995/wrs.1994.226

Blas, F. Gidenne, T. (1998) Digestion of starch and sugars. In: De Blas, C., Wiseman, J., Eds. The Nutrition of the Rabbit. Wallingford: CAB Int., pp. 17-38.

Boeckner, L.S., Schnepf, M.I., Tungland, B.C. (2001) Inulin: a rewiev of nutritional and health implications. Advances in food and nutrition research, 43, 1–63. DOI: https://doi.org/10.1016/s1043-4526(01)43002-6

Bónai, A., Szendrő, Z., Fébel, H., Kametler, L., Tornyos, G., Horn, P., Kovács, F., Kovács, M. (2010) Effect of inulin supplementation and age on performance and digestive parameters in weaned rabbits. World Rabbit Science, 18, 121–129. DOI: https://doi.org/10.4995/wrs.2010.5883

Carabaño, R., Badiola, I., Licois, D., Gidenne, T. (2006) 4.2. The digestive ecosystem and its control through nutritional or feeding strategies. Recent advances in rabbit sciences, 211.

Ciéslik, E., Gębusia, A., Florkiewicz, A., Mickowska, B. (2011) The content of protein and of amino acids in Jerusalem artichoke tubers (*Helianthus tuberosus* L.) of red variety Rote Zonenkugel. Acta Scientarium Polonorum, Technol. Aliment., 10 (4), 433–411.

Debray, L., Le Huerou-Luron, I., Gidenne, T., Fortun-Lamothe, L. (2003) Digestive tract development in rabbit according to the dietary energetic source: colleration between whole tract digestion, pancreatic and intestinal enzymatic activities. Comparative Biochemistry and Physiology Part A, 135, 443–455. DOI: https://doi.org/10.1016/s1095-6433(03)00112-0

Gallois, M., Gidenne, T., Fortun-Lamothe, L., Le Huerou-Luron, I., Lalles, J.P. (2005) An early stimulation of solid feed intake slightly influences the morphological gut maturation in the rabbit. Reproduction Nutrition Development, 45, 109–122. DOI: https://doi.org/10.1051/rnd:2005008

Gibson, G.R., Roberfroid, M.B. (1995) Dietary modulation of the human colonic microbiota: Introduction the concept of prebiotics. Journal of Nutrition, 125, 1401–1412. DOI: https://doi.org/10.1093/jn/125.6.1401

Gidenne T. (2003) Fibres in rabbit feeding for digestive troubles prevention: respective role of low-digested and digestible fibre. Livestock Production Science, 81, 105–117. DOI: https://doi.org/10.1016/S0301-6226(02)00301-9

Gidenne, T., Carabaño, R., Garcia, J., De Blas, C. (2010) Fibre digestion. In: Wiseman, J., De Blas, C., Eds. Nutrition of Rabbit. Wallingford: CABI, pp. 66–82.

Gómez-Conde, M.S., De Rozas, A.P., Badiola, I., Pérez-Alba, L., De Blas, C., Carabaño, R., García, J. (2009) Effect of neutral detergent soluble fibre in digestion, intestinal microbiota and performance in twenty five day old weaned rabbits. Livestock Science, 125, 192–198. DOI: https://doi.org/10.1016/j.livsci.2009.04.010

Guttiérrez, I., Espinosa, A., García, J., Carabaño, R., De Blas, J.C. (2002) Effect of levels of starch, fibre, and lactose on digestion and growth performance of early-weaned rabbits. Journal of Animal Science, 80, 1029–1037. DOI: https://doi.org/10.2527/2002.8041029x

Kays, S.J., Kultur, F. (2005) Genetic Variation in Jerusalem Artichoke (*Helianthus tuberosus* L.) Flowering Date and Duration. HortScience, 40 (6), 1675–1678. DOI: http://dx.doi.org/10.21273/HORTSCI.40.6.1675

Kvaček, J. (2011) Certifikovaná metodika využití topinamburu v KS pro zvířata. ISBN: 978-80-7403-083-3.

Kvaček, J., Čížek, M., Čepl, J. (2013) Certifikovaná metodika využití topinamburu v KS pro zvířata.

Kvaček, J., Vacek, O. (2011) Present state of JA in Czech and application research in feeding livestock and animals in ZOOs.

Mansourielaheh, M., Sani, A., Milani.,E, Nourbakhsh, L. (2016) Prebiotic effect of Jerusalem artichoke (*Helianthus tuberosus*) fructans on the growth performance of Bifiobacterium bifium and *Escherichia coli*. Asian Pacifik Journal of Tropical Disease, 6, 385-389. DOI: https://doi.org/10.1016/S2222-1808(15)61053-2

Mareček, E., Kvaček, J. (2009) Využití netradičních surovin ve výživě králíků a cílená dietetika při jejich odchovu a výkrmu. In: Sborník referátů X. celostátního semináře Nové směry v intenzivních a zájmových chovech králíků, Praha ČZU, 47-54. ISBN: 978-80-7403-043-7

Olehlová, K. (2018) Nutriční management koně. Available at: https://docplayer.cz/2070788-Nutricni-management-kone.html [Accessed 10 May 2022]

Őztűrk, H. (2008) Effects of inulin on rumen metabolism in vitro. Ankara Üniversitesi Veteriner Fakültesi Dergisi, 55, 79–82. DOI: https://doi.org/10.1501/Vetfak_0000000302

Roberfroid, M.B. (1999) Concepts in Functional Foods: The Case of Inulin and Oligofructose. The Journal of Nutrition, 129, 1398S–1401S. DOI: https://doi.org/10.1093/jn/129.7.1398S

Samanta, A.K., Jayapal, N., Senani, S., Kolte, A.P., Sridhar, M. (2013) Prebiotic inulin: Useful dietary adjuncts to manipulate the livestock gut microflora. Brazilian Journal of Microbiology, 44, 1, 1-14. DOI: https://doi.org/10.1590/S1517-83822013005000023

Scapinello, C., Gidenne, T., Fortun-Lamothe, L. (1999) Digestive capacity of the rabbit during post-weaning period, according to the milk/solid feed intake pattern before weaning. Reproduction Nutrition Development, 39, 109–122. DOI: https://doi.org/10.1051/rnd:19990402

Szambelan, K., Nowak, J., Chrapkowska, K.J. (2004) Comparison of bacterial and yeast ethanol fermentation yield from Jerusalem artichoke (*Helianthus tuberosus* L.) tubers pulp and juices. Acta Scientarium Polonorum, Technol. Aliment., 3, 423–432.

Skřivanová, V. (2001) Výživa a krmení brojlerových králíků. Náš chov.

Vágner, J. (1990) Afrika - ráj a peklo zvířat. 1. Vyd. Svoboda, 221.

Volek, Z. (2017) Základy výživy brojlerových králíků, VÚŽV 2017

Van Soest, P.J., Robertson, J.B., Lewis, B.A. (1991) Methods for dietary fibre, neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583–3597. DOI: https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Yildiz, G., Sacakli, P., Gungor, T. (2006) The effect of dietary Jerusalem artichoke (*Helianthus tuberosus* L.) on performance, egg quality characteristics and egg cholesterol content in laying hens. Czech Journal of Animal Science, 51 (8), 349.

Zeman, L., Skřivanová, V., Volek, Z., Klapil, L., Klecker, D. (2005) Potřeba živin a tabulky výživné hodnoty krmiv pro králíky, Brno, MZLU, třetí vydání, 62 s.

Žaldarienė, S., Kulaitienė, J., Černiauskienė, J. (2012) The quality comparison of different Jerusalem artichoke (*Helianthus tuberosus* L.) cultivars tubers. Žemės Ükio Mokslai, 19 (4), 268–272. DOI: https://doi.org/10.6001/zemesukiomokslai.v19i4.2588