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The potential nutritional value of root dry mass from sugar beet, fodder beet and table beet

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Abstract

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The experiment was carried out at the Agricultural Institute, Shumen (Bulgaria) in 2018, with the aim to determine the potential nutritional value of the root dry mass of sugar, fodder and table beets with selection value.

Sugar beet root mass was found to have the highest values of gross and metabolizable energy, as well as milk and feed units for growth compared to table and fodder beets. The values of the indicators on the first date of harvesting exceed the total group of beet types (All Grps), respectively, by 0.2% (for GE), 7.1% (for ME), 9.1% (for Feed units for milk) and 12.1% (for Feed units for growth), and on the second collection date (October 23rd), respectively, by 1.4% (for BE), 9.0% (for ME), 10.4% (for FUM) and 13.8% (for FUG). For the period of the experiment, the difference in the values of the signs is unproven.

The amount of gross energy (55.89%), metabolizable energy (96.98%), as well as the number of feed units for milk (97.31%) and growth (97.59%) were influenced to the highest degree by the type of beet.

Correlation and regression relationships between some indicators characterizing the composition and nutritional value of the root dry mass have been derived, to be used for practical purposes.

Keywords: sugar beet; fodder beet; table beet; gross energy; metabolizable energy; feed units for milk; feed units for growth

Introduction

Along with increasing yields from agricultural plants, improving the quality of production is also important. The nutritional value of the feed to satisfy the animal's need for food depends mainly on the nutritional value of the forage mass.

Sugar beet (*Beta vulgaris L., var. Saccharifera A.*) is the main crop for sugar production in temperate countries. Grown in 121 countries, the total production of sugar beet in the world is 270 million tons from an area of 7.9 million hectares (FAO, 2019). They accumulate a lot of carbohydrates, which represent 75-80% of dry matter and include: monosaccharides (glucose, fructose, galactose), disaccharides (sucrose and maltose), polysaccharides (cellulose and hemicellulose and pectin substances). Sucrose occupies about 70-75% of the amount of carbohydrates. Sugar beet has a purifying effect on the body, increasing the level of oxygen in the blood, helping the formation of blood cells, clearing toxins, etc. It is rich in phosphorus, calcium, manganFEe, as well as vitamins C and A. Its folate (folic acid) content makes it a powerful antioxidant. It helps reduce the risk of birth defects, boosts detoxification and helps cleanse the blood and liver. It is a source of betaine, which helps protect cells, proteins and enzymes from environmental stress. Helps fight inflammation, protects internal organs, improves vascular risk factors, helps prevent many chronic diseases. The effect of pectin on lowering cholesterol and tissue fat concentration was studied in relation to fat level and type of carbohydrate in rats (Chang ML, Johnson MA1 1976). Pectin increases the rate of removal of serum cholesterol, and a similar trend is observed in the accumulation of cholesterol in the liver. In the research of Sudheesh (1999), a significant hypolipidemic effect was established, the concentrations of cholesterol, triglycerides, phospholipids and free fatty acids were significantly reduced in the serum and tissues of experimental animals. HMG CoA reductase activity was found to be increased. Pectin administration decreased the activity of glucose-6-phosphate dehydrogenase and malate dehydrogenase, while increasing the activity of lipoprotein lipase and plasma LCAT. Incorporation of labeled C acetate into free cholesterol was significantly higher in the liver of pectin-treated rats. The concentrations of bile acids (hepatic and fecal) and fecal neutral sterols showed a significant increase in the groups receiving pectin.

Fodder beet (*Beta vulgaris subsp maritima*), belonging to Amaranthaceae (formerly *Chenopodiaceae*), is a biennial plant grown for its high productivity and nutritional qualities. It is a valuable source of forage in ruminant diets. The high content of sugar in the feed, of vitamins and minerals, the low content of fiber makes the ration with better taste, digestibility and digestibility of rough and concentrated forages (Kikindonov, 2011; Salama & Zeid, 2017)). This crop is associated with favorable agronomic characteristics such as tolerance to salinity and drought, less water requirement and proper nutritional characteristics such as production of forage and silage with high nutritional value, good taste and good resistance to environmental changes.

Fodder beet shoots and roots are palatable and easily digestible and liked by most livestock (Chatterjee and Das, 1989). The chemical composition of fodder beet varies between cultivars, growing conditions, and among shoots and roots of the plant (Magat and Goh, 1990). The roots have up to 60% sugars (mainly sucrose), low crude protein (approximately 10%) and neutral detergent fibre (approximately 12%) contents (Matthew et al., 2011). The shoots make up approximately one third of the DM of the whole plant (Clark et al., 1987), and are characterized by their high protein content, around 11.4 – 15.8% (Nadaf et al., 1998). While the shoots and roots may be used to feed the animals, the main fodder is the tuberous roots (Ibrahim, 2005).

Scientific studies indicate that the participation of fodder beet in the ration of dairy animals increases milk production (180 kg to 450 kg additional milk) in a period when there is a deficit of other fodder crops. (Singh et al., 2013). Dalley et al., (2020) reported that his experience of feeding cows with fodder beet resulted in better reproductive performance and had greater average milk solids, fat and protein than others applying other forages.

The taste qualities of salad beets have been known for a long time. The root and leaves contain valuable nutrients, pigments and vitamins, hydrocarbons, mineral salts and organic acids. Apart from being a high-yielding crop, during storage, root crops do not lose their nutritional qualities (Uchkunov &. Uchkunova, 2009).

The aim of the study was to determine the potential energy nutritional value of root crop dry mass of sugar, fodder and table beets

Material and Methods

In 2018, in the experimental field of the Agricultural Institute – Shumen, field experiments were carried out to evaluate the selection value of standard varieties of sugar, fodder and salad beets, and their pollinators. During the research period, the developed technologies for beet growing are optimized with an emphasis as raw material for fodder and determining the growth dynamics of pollinators and their hybrids from comparative experiments to establish the genotypic response.

Agroclimatic characteristic in the area of the experiment*.*

The climatic characteristic of the area is an important factor for plant growth and development (Arechiga and Carlos 2000, Hakansson et al. 2002; Albayrak and Çamaş, 2007). Light intensity affects dry matter accumulation (Picken et al. 1986), and soil microflora favors nutrient uptake, yield and quality of plant production (Markoski et al., 2015). Climatic conditions in the year of the experiment are characterized as unfavorable.

An uneven distribution of precipitation, drought with high temperatures during critical phases of beet development was observed (Figures 1 and 2). The amount of precipitation

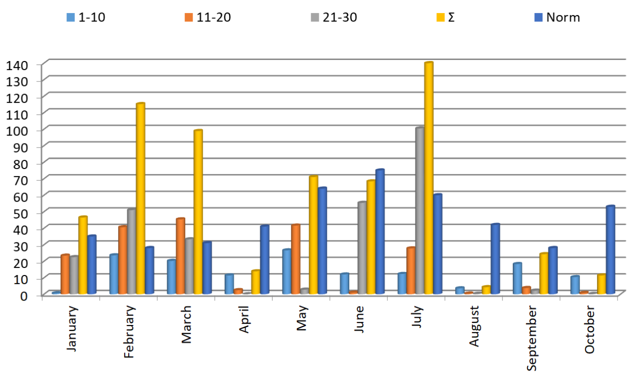

Fig. 1. Total amount of rain for 10 days (mm)

in the months of April (13.9 mm), June (68.4 mm), August (4.3 mm), September (24.3 mm) and October (11.4 mm) is lower than the norm, and the air temperature is 18.2°C (for April), 20.8°C (for June), 25.5°C (for August), 17.8°C (for September) and 12.9°C (for October).

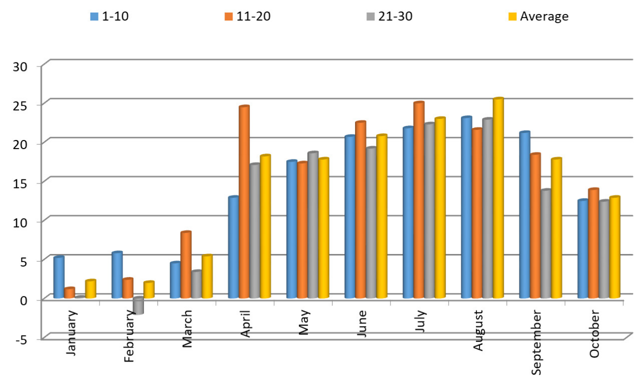

Fig. 2. Air temperature for 10 days and average for the period (°C)

The field experience was established by the method of long plots in 4 replications, with a harvest plot size of 8.4 m2 and included determination of the chemical composition and energy value of dry pulp of root crops (for standard varieties). The following origins were used:

Type	Standard cultivars	Pollinizers
Sugar beet	Diex and Peshtera	5319R
Fodder beet	Sasha, Preslav and Tetragold	
Table beet	Radost 1 and Radost 3	Radost

Plant sowing was done manually, at 70 cm row spacing (10 000 plants/da), in 6 replicates. The finished product was realized in the months of August (09.08.) and October (23.10.). The chemical analysis of the root crops was performed after drying the ground pulp obtained from the two harvesting dates (separately). The soil type is carbonate chernozem with a slightly alkaline reaction of the soil solution.

In the analytical laboratory of the Institute of Mountain Animal Breeding and Agriculture – Troyan, the main chemical composition of the dry mass was analyzed according to the Weende analysis: Crude protein (CP = N × 6.25, g/kg) according to Keldahl (according to BDS/ISO-5983); Crude fiber (CFiber, g/kg); Crude fats (CFat, g/kg) (according to ISO-6492) – by extraction in a Soxhlet type extractor; Ash – mineral substances (g/kg) – (according to ISO-5984) decomposition of the organic substance, by gradually burning the sample in a muffle furnace at 550°C; Dry matter (DM, g/kg) – empirically calculated from % of moisture; Nitrogen free extracts (NFE, %) = 100 – (CP, % + CFiber, % + CFat, % + Ash, % + Moisture, %) converted to g kg; Calcium (Ca, g/kg) – complexometrically and Phosphorus (P, g/kg) – with a vanadate-molybdate reagent according to the Gerike and Kurmis method with a spectrophotometer (Agilent 8453 UV – visible Spectroscopy System), measuring in the 425 ηm range.

The nutritional value of the dry root mass is estimated according to the Bulgarian system as Feed units for milk (FUM, number in kg DM) and Feed units for growth (FUG, number in kg DM), and calculated based on equations, according to the experimental values of CP, CFiber, CFat and NFE, calculated by using the digestibility coefficients by Todorov (2010): Gross energy (ME, MJ/kg DM) = 0.0242*CP + 0.0366*CFat + 0.0209*CFiber + 0.017*NFE – 0.0007*Zx and Metabolizable energy (ME, MJ/kg DM) = 0.0152*CFatP + 0.0342*CFat + 0.0128*CFatFiber + 0.0159*CFatNFE – 0.0007*Zx.

Data obtained from the experiment were statistically processed by analysis of variance (ANOVA) and the Statistica for Windows 10 program.

Results and Discussion

Root dry mass of sugar beet (at both harvest dates) had the highest values of gross and metabolizable energy, as well as feed units for milk and growth compared to that of salad and fodder beet (Table 1). The values of the indicators on the first harvest date (19.08) exceed the total group of beet types (All Grps), respectively, by 0.2% (for BE), 7.1% (for ME), 9.1% (for FUM) and 12.1% (for FUG), and in the second collection date (23.10.), respectively, by 1.4% (for GE), 9.0% (for OE), 10.4% (for FUM) and 13.8% (for FUG).

Contemporary assessment of the quality of the root mass is based on the energy nutritional value and is determined by the feed units for milk and growth. The feed value was established on the basis of the chemical composition – content of crude protein, fat, fiber, nitrogen-free extracts and digestibility coefficients indicated by Todorov (2010). From the analysis of the data, we find that in the root mass realized in the month of August (09.08.) no significant difference in the amount of gross energy was found for the beet types studied. In contrast, the difference (at $P < 0.01$ and $P < 0.001$) in the content of metabolizable energy and the number of feed units was statistically proven. The dry root mass of sugar beet, compared to that of salad and fodder beet, is respectively, 19.7% and 10.0% higher in energy content for regulating metabolic processes in the animal organism. Similar results were obtained regarding the number of feed units for milk and growth. The values of sugar beet are higher compared to the other types of

Table 1. Nutritional value of root dry mass of sugar beet, table beet and fodder beet

Beet types	GE, MJ/ kg DM	ME, MJ/ kg DM	FUM, kg	FUG, kg
09.08.				
Sugar	16.51a	12.59***	1.32***	1.48***
Table	16.44a	10.52**	1.05**	1.10**
Fodder	16.48a	11.45**	1.17**	1.27**
All Grps	16.48	11.75	1.21	1.32
Std.Dev.	0.30	0.91	0.12	0.17
Variance	0.09	0.83	0.01	0.03
Std.Err.	0.10	0.30	0.04	0.06
Minimum	15.95	10.38	1.04	1.08
Maximum	17.04	12.87	1.36	1.54
23.10.				
Sugar	16.86*	13.14***	1.38***	1.57***
Table	16.38a	10.59*	1.06*	1.12*
Fodder	16.50a	11.60*	1.19*	1.29*
All Grps	16.63	12.06	1.25	1.38
Std.Dev.	0.23	1.13	0.14	0.20
Variance	0.05	1.27	0.02	0.04
Std.Err.	0.08	0.38	0.05	0.07
Minimum	16.23	10.09	1.00	1.04
Maximum	16.89	13.21	1.39	1.58
Average for 09.08.–23.10.				
09.08.	16.48a	11.75a	1.21a	1.32a
23.10.	16.63a	12.06a	1.25a	1.38a
All Grps	16.56	11.9	1.23	1.35
Std.Dev.	0.27	1.01	0.13	0.18
Variance	0.07	1.01	0.02	0.03
Std.Err.	0.06	0.24	0.03	0.04
Minimum	15.95	10.09	1.00	1.04
Maximum	17.04	13.21	1.39	1.58

The differences between the types of beet is statistically significant *P < 0.05, **P < 0.01, ***P < 0.001 and insignificant when the values are marked with the same letters.

beet respectively by 25.7% (compared to salad) and 12.8% (compared to fodder) for FUM and 34.5% (compared to salad) and 16.5% (compared to fodder) for FUG. Metabolizable and net energies (expressed by FUM and FUG) for salad (with 10.5% – OE, with 13.2% – FUM and with 16.7% – FUG) and fodder (with 2.6% – ME, with 3.3% – FUM and with 3.8% – FUG) beets are lower compared to the total of the group (All Grps).

The sugar beet root mass harvested on the second harvest date (23.10.) has a proven (at P < 0.05 and P < 0.001) higher amount of gross energy, metabolizable energy and feed units for milk and growth compared to salad and fodder beet, respectively with 2.9% and 2.2% (for GE), 24.1% and 13.3% (for ME), 30.2% and 16.0% (for FUM), 40.2% and 21.7% (for FUG).

On average for the period (09.08.–23.10.) the difference in the values of the indicators indicated in Table 1 is insignificant. The root dry mass harvested in the summer month is distinguished by lower values of the studied indicators compared to those obtained from the dry mass in the autumn period and compared to the average values of the group (All Grps).

The type of beet and the date of reporting (harvesting) influence the energy nutritional value of the root dry mass (Table 2). According to the data analysis, the amount of gross energy was most influenced by the type of beet (55.89%), followed by the interaction of the type and the reporting date (33.72%), and the independent influence of the reporting date (10.39%).

This sequence of the factorial influence is not preserved for the other indicators (object of the study). The type of crop (sugar, salad and fodder beet) causes a high factorial variance regarding metabolizable energy content (96.98%), number of feed units for milk (97.31%) and feed units for growth (97.59%). In contrast, reporting date and the interaction of the two factors have little effect on these indicators. The degree of influence of the reporting date on the amount of exchange energy is 1.71%, and the interaction of the factors – 1.31%. Similar are the results regarding the net energy (expressed by FUM and FUG) in the dry matter of the root mass. The influence of the reporting date expressed in percentages for KEM and FUG is 1.59% and 1.48%, respectively, and the interaction of the two factors is 1.1% and 0.93%, respectively. Correlational dependences were established between some indicators characterizing the composition and nutritional value of the root dry mass in sugar, salad and fodder beets (Table 3). The amount of mineral substances has a high positive correlation with the content of crude protein and nitrogen (r = 0.87). The correlation coefficient of the metabolizable energy, feed units for milk and growth with the carbohydrate fraction (nitrogen free extracts) has a high absolute value (r = 0.99-1.00), to which strongly expressed empirical linear dependencies correspond.

Crude protein as the main component in the composition of the dry matter has a high positive correlation dependence (r = 0.99) with the concentration of the macroelement – nitrogen. The theoretical regression line and the equation of the regression relationship between the content of crude protein and nitrogen in the dry root mass of the studied beet types are depicted in Figure 3, where y = 1.0373 + 0.1311*CP at a high coefficient of determination – R = 0.996 (P < 0.0000).

The equations (Figure 4) by which it is possible to predict the amount of FUM and FUG through NFE are: y = 0.3352 + 0.0013*NFE and y = 0.0973 + 0.0018* NFE with a coefficient of determination – R = 0.996 (with significance level P < 0.0000).

In contrast, a very high negative correlation (r = from -0.91 to -0.99) was found between the concentration of crude protein, mineral matter and nitrogen with the content of nitrogen-free extracts, metabolizable energy and feed units for milk, and growth.

Table 2. Influence of the factors (type and date of harvest) on the energy nutritional value of sugar beet, table beet and fodder beet

Factors	SS	Degree of Freedom	MS	F	p	Partial eta-squared	Observed power (alpha = 0.05)	Degree of influence, %
BE, MJ/kg								
Type (A)	0.242	2	0.121	1.95	0.185	0.245	0.325	55.89
Date of harvest (B)	0.045	1	0.045	0.72	0.413	0.057	0.122	10.39
A*B	0.146	2	0.073	1.17	0.343	0.163	0.209	33.72
ME.MJ/kg								
Type (A)	15.491	2	7.745	85.26	0	0.934	1	96.98
Date of harvest (B)	0.273	1	0.273	3.01	0.108	0.201	0.358	1.71
A*B	0.209	2	0.104	1.15	0.35	0.161	0.206	1.31
FUM. kg DM								
Type (A)	0.25	2	0.13	87.05	0	0.94	1	97.31
Date of harvest (B)	0	1	0	2.84	0.12	0.19	0.342	1.59
A*B	0	2	0	0.99	0.4	0.14	0.182	1.1
FUG. kg DM								
Type (A)	0.50087	2	0.25	86.302	0	0.935	1	97.59
Date of harvest (B)	0.00761	1	0.008	2.623	0.131	0.179	0.32	1.48
A*B	0.00478	2	0.002	0.824	0.462	0.121	0.159	0.93

Table 3. Correlation relationships between the main chemical indicators and the energy nutritional value of root dry mass of sugar, table and fodder beet (at both harvest dates)

Vari-able	Means	CP, g/kg CB	CFat, g/kg CB	CFiber, g/kg CB	Ash, g/kg CB	NFE, g/kg CB	Ca, g/kg CB	P, g/kg CB	N, g/kg CB	БЕ, MJ/kg DM	ME, MJ/kg DM	FUM, kg	FUG, kg
CP	141.93	1	0.57	0.13	0.87	-0.94	0.24	0.60	0.99	-0.22	-0.91	-0.92	-0.92
CFat	5.32	0.57	1	0.12	0.47	-0.57	0.51	0.27	0.55	0.19	-0.53	-0.55	-0.56
CFiber	67.97	0.13	0.12	1	0.51	-0.44	0.42	0.44	0.13	-0.67	-0.50	-0.49	-0.47
Ash	80.58	0.87	0.47	0.51	1	-0.98	0.26	0.62	0.87	-0.63	-0.99	-0.98	-0.98
NFE	704.20	-0.94	-0.57	-0.44	-0.98	1	-0.33	-0.66	-0.94	0.46	0.99	0.99	0.99
Ca	9.38	0.24	0.51	0.42	0.26	-0.33	1	0.34	0.24	0.07	-0.30	-0.31	-0.32
P	1.76	0.60	0.27	0.44	0.62	-0.66	0.34	1	0.61	-0.27	-0.65	-0.66	-0.66
N	19.65	0.99	0.55	0.13	0.87	-0.94	0.24	0.61	1	-0.23	-0.91	-0.91	-0.92
BE	16.56	-0.22	0.19	-0.67	-0.63	0.46	0.07	-0.27	-0.23	1	0.54	0.51	0.49
ME	11.90	-0.91	-0.53	-0.50	-0.99	0.99	-0.30	-0.65	-0.91	0.54	1	0.99	0.99
FUM	1.23	-0.92	-0.55	-0.49	-0.98	1.00	-0.31	-0.66	-0.91	0.51	0.99	1	0.99
FUG	1.35	-0.92	-0.56	-0.47	-0.98	1.00	-0.32	-0.66	-0.92	0.49	0.99	0.99	1

(P <0.05)

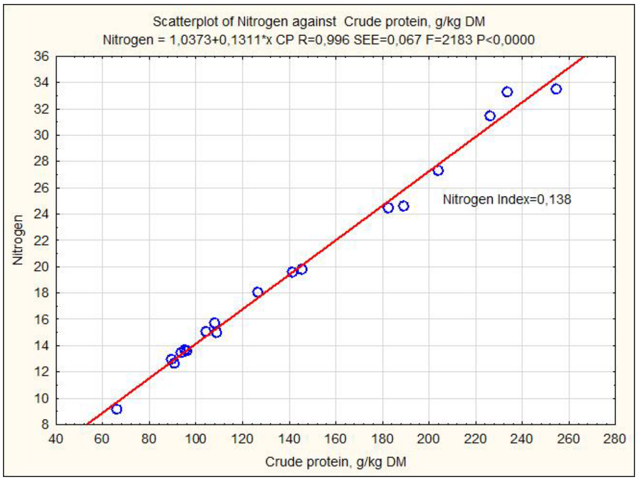

Fig. 3. Graphical regression model for determination of nitrogen by crude protein in dry root mass of sugar table and fodder beets

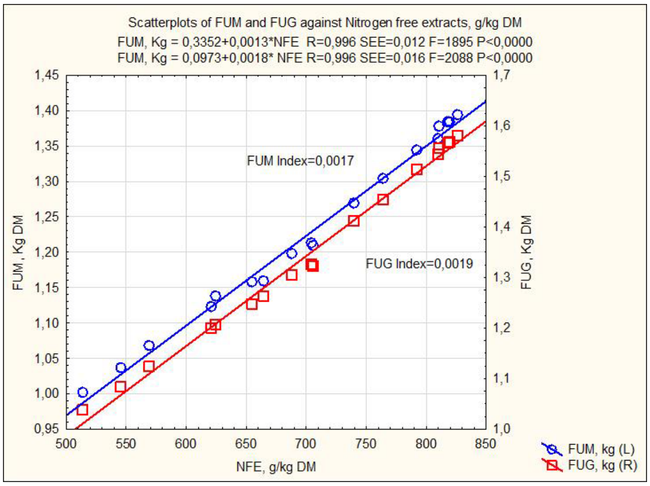

Fig. 4. Graphical regression model for determination of FUM and FUG by NFE in dry root mass of sugar, table and fodder beets

Conclusions

Sugar beet root mass was found to have the highest values of gross and metabolizable energy, as well as milk and feed units for growth compared to table and fodder beets.

The values of the indicators on the first date of harvesting (August 19th) exceed the total group of beet types (All Grps) respectively by 0.2% (for GE), 7.1% (for ME), 9.1% (for Feed units for milk) and 12.1% (for Feed units for growth), and on the second collection date (October 23rd), respectively, by 1.4% (for BE), 9.0% (for ME), 10.4% (for FUM) and 13.8% (for FUG).

For the period of the experiment, the difference in the values of the signs is unproven. The root dry mass harvested in the summer months is distinguished by lower values of the studied indicators compared to those obtained in the autumn period.

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