THE PHYSICAL PROPERTIES OF SEEDS AND THE BIOCHEMICAL COMPOSITION OF THE STRAW OF ROMANIAN *FESTUCA* CULTIVARS GROWN UNDER THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

The Romanian cultivars of tall fescue *Festuca arundinacea* ('Brio', '*Valrom*'), meadow fescue *Festuca pratensis* (*'Tâmpa'*, *'Transilvan 2'*) and red fescue *Festuca rubra* ('*Cristina BV*', '*Căprioara*'), grown in the experimental sector of National Botanical Garden (Institute), Chișinău, served as research subjects. The results of the research on the physical properties of the seeds and the biochemical composition of the biomass, namely – straw, from the plants of the above-mentioned cultivars are presented in this article. Our research has revealed that the characteristic dimensions (length x width x thickness) of the studied seeds vary in the following ranges $\ell:b:\delta \approx$ (5.70-6.40) : (1.20-1.35) : (0.70-80) mm. The morphological structure of the studied seeds is in accordance with type 4 "elongated" ($\ell > b \not\approx \delta$). The friability level of the seeds is relatively low: the angle of repose is about α=34.3°-43.0° and the flow angle on steel surface is α_1=29.1°-33.1°, on wood α_1=37.0°-45.2° and on enamelled surface α_1=26.7°-32.7°. The straw collected from the studied cultivars contained 28-83 g/kg CP, 417-562 g/kg CF, 469-595 g/kg ADF, 720-889 g/kg NDF, 60-91 g/kg ADL, 0-60 g/kg TSS, 251-294g/kg HC, 406-504 g/kg Cel. The obtained values of the physical properties of seeds are necessary for the justification of the choice, the calculation and the correct adjustment of the technical means of conditioning and sowing the seeds in the soil, and the obtained data on the biochemical composition indicate possibilities of using straw as animal feed or as a substrate for the production of renewable energy.

Key words: straw biochemical composition, *Festuca* spp., straw feed value, seed physical properties, renewable energy

The risk of climate change, air pollution and emissions greenhouse gases, the rising prices of production means and energy, decreasing farmland area and reducing reserves of fossil energy, as well as uncertainties about future reliability of supply with food and energy are currently prominent concerns. In these conditions of uncertainty, it is an imperative task to carry out a complex of activities to maintain biodiversity and use rationally the potential of plant species from the local flora in the circular economy.

Grasslands are ecosystems with a wide diversity of herbaceous plant species, in full harmony with the habitat conditions; traditionally they had an important economic value as a source of feed for animals, but also for the collection of medicinal, aromatic, technical, food and craft plants and, in the last decades, also as a source of energy biomass.

Permanent grasslands in the Republic of Moldova constitute 10.1% of the territory, their productivity is low and of poor quality, reaching 400-600 kg/ha of hay. In order to increase their productivity, it is necessary to prepare management strategies, to provide seeds of various herbaceous species for re-sowing and technical means of conditioning and incorporation of seeds and fertilizers into the soil, harvesting and storage.

Currently, in the Catalogue of Plant Varieties of the Republic of Moldova, there are no grass cultivars registered, but in Romania, cultivars with high productivity and adapted to different environmental conditions have been created and registered, and grassland management strategies and recommendations for the establishment of plantations for the production of seeds have been developed (Maruşca T. *et al*, 2021, 2014; Ene T.A., Mocanu V., 2016).

The Plant List includes 1741 scientific plant names of species rank for the genus *Festuca*, family Poaceae, of these 646 are accepted species names; *Festuca arundinacea*, *Festuca pratensis*,

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Festuca rubra are among the perennial species with the highest frequency in the floristic composition of permanent and temporary grasslands, buffer strips and lawns in green spaces. *Festuca* species have been recommended as components of the mixtures with other species of Poaceae and Fabaceae for biodiversity restoration of grasslands, water conservation and soil protection (Revenco E., Ţîţei V., 2021).

In our previous joint research, we presented results regarding the productivity and forage value of the harvested fresh mass and the possibilities of preserving it as hay and silage, as well as the quality as substrate for the production of biomethane in anaerobic digesters, of several Romanian cultivars of fescue grown in the central area of Moldova (Ţîţei V. *et al,* 2019, 2021).

Making use of the full potential of *Festuca* plant species requires studying the properties and physical characteristics of the seeds, as well as the biochemical composition of the plant mass (straw) from the aforementioned plants. These characteristics are of particular importance, being used in the design and management of the technological operations of conditioning (cleaning, calibration, drying, treatment), storage, transport and sowing (Ene T, Mocanu V., 2016). It is well known that the values of the above-mentioned characteristics depend, to a large extent, on the growth conditions of the plants, on the one hand, and, on the other hand, determine the fields of practical use of seeds and straw. Therefore, it is important to study the characteristics of seeds and plant mass obtained from *Festuca* plants grown under the pedo-climatic conditions of the Republic of Moldova, this being the goal of our research.

MATERIALS AND METHODS

The Romanian cultivars of *Festuca* species created in Research-Development Institute for Grassland Brasov: 'Brio' of tall fescue *Festuca arundinacea*, 'Tâmpa' and 'Transilvan 2' of meadow fescue *Festuca pratensis*, '*Căprioara*' and '*Cristina*' of red fescue *Festuca rubra,* and ''*Vlarom*'' of tall fescue *Festuca arundinacea* created in University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca which were grown in the experimental sector of National Botanical Garden (Institute), Chișinău, latitude 46°58′25.7″N and longitude N28°52′57.8″E, served as research subjects and traditional cereal and forage crop oat *Avena sativa* 'Sorin' – as control.

The samples of grass seeds and straw were collected in the third growing season. The evaluation and analysis of the physical properties of the seeds of each species and cultivar were carried out based on the measurement of the following parameters: length, width, thickness, morphological structure, friability (angle of repose α, angle of friction α_1).

The angle ***α*** was determined by two methods: a) *general*, measuring the height *h* of the cone with a depth calliper and the diameter of the base *D* in two perpendicular planes with the metal ruler KLB 300 x 19 x 0.5 mm; the angle α was calculated according to the formula $tg\alpha = 2h/D$; b) *local*, measuring the angle α by applying the digital inclinometer on the inclined surface of the cone. The flow angle α_1 of the seeds was measured using a table with the upper surface rotating vertically. On this surface, it is possible to attach plates made of different materials. We used plates of steel 10, wood and enamelled steel. The angle α_1 was measured using a digital inclinometer.

For biochemical analysis, grass straw samples were dried in a forced air oven at 60°C, milled in a beater mill equipped with a sieve with diameter of openings of 1 mm, and some assessments of the main biochemical parameters: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) have been made by near infrared spectroscopy (NIRS) technique using the equipment PERTEN DA 7200. The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures.

The Theoretical Ethanol Potential (TEP) was calculated according to the equations of Goff B.M. *et al* (2010) based on conversion of hexose (H) and pentose (P) sugars.

RESULTS AND DISCUSSIONS

The obtained results (*table 1*) have demonstrated the following values of the characteristic dimensions (length ℓ · width b · thickness δ) for the studied seeds: *Festuca rubra* ℓ:b:δ≈ 5.90-6.30:1.27-1.34: 0.74-0.77 mm; *Festuca pratensis* ℓ:b:δ≈ 6.10-6.23:1.30-1.35:0.76-0.78 mm; *Festuca arundinaceae* ℓ:b:δ≈ 5.70-6.40:1.20 -1.35:0.70-0.80 mm, the highest values were recorded by the cultivars 'Căprioara', 'Tâmpa' and 'Vlarom'. We noticed that the seed sizes of all *Festuca* species have a relatively constant ratio: ℓ:b:δ≈8:1.7:1. The dimensions of oat seeds have the following values ℓ:b:δ≈ 9.6:2.8:2.0 mm, the ratio of the dimensions varying within the limits ℓ:b:δ≈4.8:1.4:1, differing from the ratio of *Festuca* seeds.

In the opinion of specialists (Matei G., Feher E., 2010; Hailis G. *et al,* 1998), the shape of the seeds most influences their friability. The seeds of spherical of near-spherical shape are characterized by the highest flow capacity. The more the shape of the seeds differs from the spherical one, the more the friability decreases. The analyses of the dimensions and morphological structure revealed the fact that the seeds of the species of the genus *Festuca*, as well as those of oat, have morphological structure according to type 4 ‘elongated’ ($l > b \neq \delta$). However, the surface of the oat seeds is smooth, therefore the coefficient of friction is low, while the *Festuca* seeds have a rough surface, covered with a coating that easily detaches from the grain and worsens the flow capacity, especially on wooden surfaces, increasing the coefficient of friction.

The obtained values of the angle of repose α and angle of friction α_1 confirm the results of the dimensional and morphological analyses: the friability of *Festuca* seeds is relatively low and has the following values: *Festuca rubra* ‘Cristina’: angle of repose (general method) α= 39.8° and angle of friction α_1= 31.8° – on steel, α_1= 42.0° – on wood, α_1= 32.7° – on enameled surface; *Festuca pratensis* ‘Transilvan’ – α= 33.0° and angle of friction α_1= 30.0° – on steel, α_1= 37.0° – on wood, α_1= 31.3° – on enameled surface; *Festuca arundinacea* 'Vlarom' – α= 36.0°, α_1= 30.0° – on steel, α_1=43.0°– on wood and α_1=26.7°– on enameled surface. The situation is the same in the case of seeds of other cultivars ('Căprioara', 'Tâmpa', 'Brio'), the difference between the values of angles α and α_1 being mostly ±0.8° for seeds of the same species. The natural slope angle α measured by the local method has values by 3°-6° higher in relation to the general method; the given difference is explained by the fact that the studied seeds have a high coefficient of internal friction and higher relative length of the seeds, therefore, they form cones with uneven surfaces.

Table 1

The results of the evaluation of the physical characteristics of the seeds of Romanian cultivars

Species and cultivars	Dimensional parameters, mm			Angle of repose **α**, methods			Flow angle **α₁**, surfaces		
	L	**b**	**δ**	general	local	average	steel	wood	enamel
Festuca arundinacea 'Brio'	5.70 ±0.60	1.20 ±0.30	0.70 ±0.10	35.0 ±0.8	38.1 ±1.6	36.6	31.7 ±0.3	42.0 ±0.7	27.7 ±0.3
Festuca arundinacea 'Vlarom'	6.40 ±0.50	1.35 ±0.30	0.80 ±0.10	36.0 ±0.9	38.7 ±2.2	37.4	30.0 ±0.2	43.0 ±0.5	26.7 ±0.3
Festuca pratensis 'Tâmpa'	6.23 ±0.58	1.35 ±0.30	0.78 ±0.12	34.9 ±0.7	40.6 ±2.6	37.8	29.1 ±0.6	45.0 ±0.6	32.3 ±0.5
Festuca pratensis 'Transilvan 2'	6.10 ±0.60	1.30 ±0.40	0.76 ±0.08	33.0 ±0.7	35.6 ±2.9	34.3	30.0 ±0.8	37.0 ±0.6	31.3 ±0.3
Festuca rubra 'Căprioara'	6.30 ±0.80	1.34 ±0.50	0.77 ±0.11	39.2 ±2.1	45.9 ±2.1	42.6	33.1 ±0.8	45.2 ±0.8	30.4 ±0.7
Festuca rubra 'Cristina'	5.90 ±0.60	1.27 ±0.40	0.74 ±0.09	39.8 ±1.5	46.1 ±5.5	43.0	31.8 ±0.7	42.0 ±0.8	32.7 ±0.6
Avena sativa 'Sorin' control	9.60 ± 1.20	2.80 ±0.40	2.00 ±0.10	29.2 ± 0.3	30.8 ± 0.6	30.0	25.2 ± 0.2	28.8 ± 1.2	23.7 ± 0.3

Table 2

The biochemical composition and fodder value of the grass straw of Romanian cultivars

Indices	*Festuca arundinacea* 'Brio'	*Festuca pratensis*		*Festuca rubra*		*Avena sativa 'Sorin'*
		'Tâmpa'	*'Transilvan 2'*	'Căprioara'	'Cristina'	
Crude protein, g/kg DM	48.0	78.0	83.0	28.0	59.0	62.0
Crude fiber, g/kg DM	489.0	426.0	417.0	562.0	457.0	487.0
Minerals, g/kg DM	80.0	98.0	105.0	78.0	90.0	82.0
Acid detergent fiber, g/kg DM	489.0	426.0	417.0	595.0	487.0	499.0
Neutral detergent fiber, g/kg DM	786.0	740.0	720.0	889.0	741.0	800.0
Acid detergent lignin, g/kg DM	60.0	61.0	63.0	91.0	60.0	56.0
Cellulose, g/kg DM	450.0	414.0	406.0	504.0	427.0	443.0
Hemicellulose, g/kg DM	276.0	265.0	251.0	294.0	254.0	301.0
Total soluble sugars, g/kg DM	45.0	47.0	54.0	0	60.0	161.0
Digestible dry matter, % DM	28.9	31.8	31.5	10.6	29.5	34.8
Digestible organic matter, % DM	25.0	27.8	27.4	7.2	25.3	30.1
Relative feed value	58	64	67	43	64	58
Digestible energy, MJ/ kg DM	9.93	10.24	10.51	8.54	10.26	10.09
Metabolizable energy, MJ/ kg DM	8.16	8.41	8.63	7.01	8.42	8.28
Net energy for lactation, MJ/ kg DM	4.18	4.58	4.64	3.20	4.44	4.30

In the scientific literature, there are data on the shape and physical properties of *Festuca* seeds. According to the data obtained by Ene T.A.& Mocanu V. (2016) *Festuca arundinacea* seeds had 6.0-8.0 mm length, 1.5-2.5 mm width, 0.5-1.5 mm thickness, 1.80-2.50 g weight of a thousand grains, 28-29 kg weight of a hectoliter, 2.6-3.6 m/s flow speed, 23-25° flow angle and 26-31° angle of repose; *Festuca pratensis* seed had 4.8-8.0 mm length, 0.9-1.6 mm width, 0.6-1.6 mm thickness, 1.80 -2.20 g weight of a thousand grains, 31-32 kg weight of a hectoliter, 2.2-3.9 m/s flow speed, 20-24° flow angle and 27-30° angle of repose; *Festuca rubra* seeds had 5.6-6.6 mm length, 0.8-1.3 mm width, 0.6-1.1 mm thickness, 1.00 -1.30 g weight of a thousand grains, 23-24 kg weight of a hectolitre, 2.5-3.2 m/s flow speed, 24-27° flow angle and 26-30° angle of repose. Shiade S.R.G.& Boelt B. (2020) mentioned that the seed characteristics of nine tall fescue cultivars were: seed area 5.1-6.0 mm^2, seed length 5.5-6.4 mm, seed diameter 1.2-1.4 mm and seed germination 86-97%. Liu Y. *et al* (2020) reported that cv. ‘'Niuniu' is characterized by dark grey color, 7.0 ± 0.8 mm length, 1.6 ± 0.1 mm width, 0.9 ± 0.1 mm thickness, 2.6 ± 0.1g weight of a thousand grains, 85% germination. Dumanoglu & Kokten K. (2022) found that the studied *Festuca* species have a long seed structure, with an average length of 5.519 mm, width of 1.033 mm, a surface area of 4.100 mm^2 and a weight of thousand grains of 1.119 g.

The optimal use of forage resources in animal diets depends on the availability of detailed information on their chemical composition, biological properties and nutritional value, which may vary between plant species, cultivars, cutting stage. For lactating ruminants (cows, goats, sheep), fibrous substances are necessary in the diet for the production of volatile fatty acids, especially acetic acid as the main precursor of fat in milk. Cellulose and hemicellulose are not limiting factors in nutrition, but when cows are grazing on pasture in early spring, they may be present in the diet of animals in low amounts. Straw and chaff have high cellulose content, are low in energy and protein and are difficult to digest, but for ruminants they serve as material to complete the diet and create a certain volume and structure of the mixture that positively influences the health of the intestinal tract and the intensity of bacterial synthesis (Coșman S. *et al*, 2018).

The results regarding the quality of the grass straw are shown in Table 2. Analyzing the results of the biochemical composition of the grass straw of studied *Festuca* cultivars, we found that the nutrient content varied in comparison with oat straw. It has been found that meadow fescue straw is characterized by high content of protein (7.8-8.3%) and minerals (9.8-10.5%) and optimal crude fiber (40.6-41.4%). Tall fescue straw has about the same amount of crude fiber and minerals, but lower protein content in comparison with oat straw. We would like to mention that straw of *Festuca rubra* 'Căprioara' has very low content of protein (2.8%), low content of minerals (7.8%), and high content of crude fiber (56.2%) in comparison with other studied grass seed straw and control variant. The amount of total soluble sugars was substantially lower in fescue straws in comparison with oat straw, but in the straw of *Festuca rubra* 'Căprioara', it not was detected.

The plant cell wall concentration is a very important limiting factor to the feeding processes and to the ability of an animal to utilize the consumed forage. Fescue straw contained higher amount of lignin. The straw of *Festuca rubra* 'Căprioara' had high cell wall concentration that had a negative effect on dry and organic matter digestibility, relative feed value and energy content. The nutritive value and energy value of fescue straw din not essentially differ from oat straw.

Some authors mentioned various findings about the nutritional value of grass straw residues. According to Guggolz J. *et al* (1971), fescue straw contained 7.0% ash, 5.2 % CP, 1.8% EE, 45.1 % CF, 40.9 % NFE, 945g/kg NDF, 535 g/kg ADF. Youngberg H.&Vough (1977) reported that tall fescue straw contained 4.8-6.4 % CP, 39.0-46.7% ADF, 69.3% cell wall constituents with 44.1-53.8 % IVOMD; red fescue straw contained 1.3-5.1 % CP, 45.2-58.5% ADF, 81% cell wall constituents with 27.3-38.9 % IVOMD, but wheat straw 1.8-3.7 % CP and 52.1-56.9% ADF. Stamm M. M. (1993) investigated grass straw residues as a feed source and remarked that the nutritional value of tall fescue straw was: 3.7-8.9% 62.1-76.6% NDF 67.9, 39.9-52.9%ADF 36.3-62.4% IVDMD, but orchardgrass straw residues – 3.7-5.7% CP, 64.3-70.6% NDF, 46.2-49.9% ADF, 46.1-50.7% IVDMD, respectively. Yoder C. (2004) remarked that the tall fescue straw contained 84 g/kg CP, 399 g/kg ADF, 637 g/kg NDF, 2.51 cal/kg ME; red fescue – 66 g/kg CP, 428 g/kg ADF, 719 g/kg NDF, 2.25 cal/kg ME; timothy grass straw – 49 g/kg CP, 382 g/kg ADF, 665 g/kg NDF, 2.50 cal/kg ME, respectively, but wheat straw – 40 g/kg CP, 500 g/kg ADF, 1.80 cal/kg ME. Bohnert D *et al* (2011) mentioned grass straw contained 3.1-8.9% CP, 32-51.5% ADF, 63-79% NDF. Hart J.M. *et al* (2012) remarked that the fescue straw contained 0.7-2.0% N, 0.05-0.2% P, 0.5-3.0% K, 0.2-0.5% Ca. According to Hejduk S.& Macháč R. (2019), the content of nutrients in the ryegrass straw was 68.3-71.3 g/kg ash, 64.1-81.4g/kg CP, 382-399 g/kg fibre, 629-656 g/kg NDF, 412-442 g/kg ADF, 215-217 g/kg HC.

Table 3

The theoretical ethanol potential of the grass straw substrates from Romanian cultivars

Indices	*Festuca arundinacea 'Brio'*	*Festuca pratensis*		*Festuca rubra*		*Avena sativa 'Sorin'*
		'Tâmpa'	*'Transilvan 2'*	'Căprioara'	'Cristina'	
Acid detergent fiber, g/kg DM	489.0	426.0	417.0	595.0	487.0	499.0
Neutral detergent fiber, g/kg DM	786.0	740.0	720.0	889.0	741.0	800.0
Acid detergent lignin, g/kg DM	60.0	61.0	63.0	91.0	60.0	56.0
Cellulose, g/kg DM	450.0	414.0	406.0	504.0	427.0	443.0
Hemicellulose, g/kg DM	276.0	265.0	251.0	294.0	254.0	301.0
Hexose sugars, g/kg	81.11	74.75	73.20	90.66	76.87	80.19
Pentose sugars, g/kg	45.40	43.58	41.29	78.36	41.78	49.51
Theoretical ethanol potential, L/t	528	493	477	580	495	541

Bioethanol, a renewable energy source, is one of the alternatives to petroleum. The use of ethanol as a fuel for internal combustion engines has certain advantages as compared with gasoline: the octane number is higher, which leads to greater detonation resistance; the freezing point of ethanol is lower, CO_2 emissions are also lower. The production of cellulosic ethanol via biological conversion consists of three critical steps: pretreatment of biomass, hydrolysis of sugar polymers (cellulose, hemicellulose etc.) to sugar monomers (hexose, pentose) and fermentation of sugar monomers to ethanol (Kumar D. & Murthy G., 2011). Analyzing the obtained results, Table 3, we would like to mention that the researched substrates of fescue straw varied in terms of cellulose content (414-504 g/kg), hemicellulose (251-294 g/kg) and acid detergent lignin (60-91 g/kg), a fact that affected the concentration of pentose and hexose carbohydrates, and the theoretical bioethanol potential reached values of 477-580 l/t organic matter. In comparison with oat straw, the substrate from *Festuca rubra* 'Căprioara' straw had higher values.

Several literature sources describe the composition of cell walls in grass straw and its cellulosic ethanol potential. Kumar D. & Murthy G. (2011) reported that straw of tall fescue contained 94.6% solids, 10.6% ash, 6.7% CP, 19.08 % water extractives, 0.32% ethanol extractives, 32.4% glucan, 14.6 % xylan, 2.9 % galactan, 3.0 % arabinan, 15.6 % acid-insoluble lignin, 1.3 % acid-soluble lignin and estimated ethanol potential to be 360.57 L/ ton biomass. Hálfdánarson H.E. (2015) reported that the highest ethanol production efficiency, of 346 l/t, was attested in the second-cut biomass of *Phleum pratense*. Pocienė L. & Kadžiulienė Ž. (2016) found that *Festuca arundinacea* biomass contained 18.93-22.37% HC, 34.13-43.75% Cel, 5.44-10.52% ADL. Tang S. *et al* (2019) have detected in the straw of *Pennisetum alopecuroides* a concentration of 41.8% Cel, 28.7% HC and 17.5% lignin and ethanol potential of 744 mg/g after alkaline treatment. Batog J. *et al* (2021) remarked that the contents of cellulose, hemicellulose, lignin and reducing sugars in *Festuca arundinacea* biomass were 33.69 %, 34.74 % 17.08 %, 100.2 g/kg, but in biomass after sodium hydroxide treatment: 50.41% 25.23 %, 12.35 %, 354.59 g/kg, respectively. Goff B.M. *et al*, (2010) found that, for sorghum biomass, the theoretical ethanol potential ranged from 560 to 610 L/t of dry biomass.

CONCLUSIONS

The dimensional ratio of the studied Romanian cultivars of *Festuca* (ℓ:b:$\delta\approx$4.8:1.4:1) proves that they are relatively smaller than the seeds of cereal crops (oats, barley, wheat etc.) and their friability is lower, therefore, when building equipment to transport them from silos or seed warehouses, we recommend the inclination of the circular flow pipes of 40° in the case of steel or enameled surfaces and 50° in the case of wooden surfaces, and for square pipes – 45° and 55°, respectively. The use of agitators in the distribution devices of the seeding machine is necessary for the uniformity of the dosage of *Festuca* seeds.

The straw of meadow fescue *Festuca pratensis* 'Căprioara' and 'Cristina' is characterized by high content of protein, minerals and cell wall constituents and can be used as fodder for animals, and the straw of *Festuca rubra* 'Căprioara' and *Festuca arundinacea* 'Brio' has high potential as substrate for the production of bioethanol.

The Romanian fescue cultivars can also be used in the Republic of Moldova to restore degraded permanent grasslands, as a component of the mixtures of plants sown to create temporary grasslands or grass strips in vineyards and orchards.

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