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Research on the Malting Properties of Domestic Wheat Varities

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Abstract: This study aimed to establish the suitability of new Croatian wheat varieties for the production of pale wheat malt. Four new varieties/breeding lines from the Agricultural Institute Osijek were tested (Indira, OSK. 378/19, OSK. 346/20, and OSK. 353/20). The quality of starting wheat, the success of the micromalting process and the quality of finished malts were analyzed. The obtained results showed that the tested varieties/breeding lines meet the quality criteria for pale beer malt, and can be classified in the II malting quality group. The vast majority of quality indicators examined in this research showed values within the limits recommended for pale wheat malt. The obtained results were very good considering that these varieties are not intended for malting, nor in their selection process attention was paid to meet the brewing quality criteria. Due to the sensory characteristics of beer, the possibility of intervention during the malting process is limited, therefore when selecting wheat for malting, attention should be paid to the lowest possible content of total and soluble proteins, which can be achieved by appropriate agrotechnical measures in cultivation.

Keywords: feed wheat; malting quality; pale wheat malt

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1. Introduction

Pale wheat malt is primarily used in the production of beer, either for wheat beers (Weizenbier, 50% or more in grist), or in combination with barley malt, such as in Alt and Kölsch beer, (up to 20% of grits) [1]. Besides, it can be used for the production of strong alcoholic beverages and also in the food and feed industry. Malt is a nutritional and enzyme-rich product, and thus is an important auxiliary or supplementary raw material in many branches of food technology (malt flour serves as an additive for the improvement of sensory properties and nutritional value of wheat flour and other types of flour). It is also a raw material for the production of malt extracts and malt syrups which are used in the production of candies, biscuits and similar products, baby food, alcoholic and soft drinks, sauces, vinegar, and many other products [2]. The by-product of malting, germ, is also a nutritionally valuable food supplement [3]. Croatia has no official malting wheat varieties (Brauweizen). However, there are a few winter wheat varieties that can, under optimal agro-technical and climatic conditions, result in quality malt. Wheat that is less suitable (characterized with lower bread making quality parameters coupled with high grain yield potential) for use in the baking industry can be utilized as a raw material for malting, considering that appropriate malting conditions are applied. Spring wheat varieties are less favorable, both in terms of the properties of their endosperm and the spectrum of their enzymes [1]. According to the German professional classification, specially developed for the needs of the brewing industry, wheat can be classified into four qualitative groups (1–4) whose malts give: (1) malts with low viscosity and poor protein degradation; (2) malts with low viscosity and enhanced protein degradation, in which the suppression of proteolysis may be accompanied by a marked deterioration of cytolytic degradation; (3) malts with high viscosity and poor protein degradation; (4) malts in which strong proteolysis is simultaneously accompanied by high viscosity [1]. It is very difficult, if not impossible, to optimize the malting process to satisfy all quality indicators. Group I is the most suitable for the production of malt, and is characterized by malt with a low content of soluble *N* (<730 mg/L) and low viscosity (<1.65 mPa × s). For the 2nd and 3rd groups, there is a possibility to use certain technological modifications of the malting process. However, the malting process can only affect a certain group of quality parameters and often the improvement of one group of parameters leads to a deterioration of the value for another group of parameters (e.g., improvement of cytolytic degradation is accompanied by the deterioration of proteolytic degradation parameters such as soluble *N*). It is clear that the malting process can affect the improvement of quality indicators only in the 2nd and 3rd groups. The fourth group is completely unsuitable for malting because it does not possess the characteristics that could be regulated to obtain quality malt. Quality requirements for wheat malt from non-brewing wheat have been described in many studies [4–8] and in general, soft varieties are generally recommended as brewing varieties due to their lower protein content [9], but they are not as much represented in the production in European countries.

As there is no established domestic brewing wheat variety, whose quality is monitored over a long period and in several different locations (as is the case for Northern European special-purpose varieties), it is difficult to assess in advance the suitability of a particular variety for malting. The Republic of Croatia is located in a climatic area where, towards the end of the wheat-growing season, the phenomenon of forced maturation is very common, which harms numerous grain quality indicators of almost all cereals. This is particularly reflected in the decreased enzyme activity of the grain [10]. Furthermore, microbiological contamination with fungi, especially of the genus *Fusarium*, commonly leads to the deterioration of numerous wheat and wheat malt quality indicators [11,12]. In general, the most favorable wheat varieties intended for malting have 11–11.5% total protein content, relatively small phenolic number, and a low share of total and soluble pentosans [13]. It is obvious that the most favorable varieties are those that meet the criteria of group I, but varieties with lower bread making properties, as well as feed or confectionery varieties can also be considered as raw material for eventual production of wheat malt. However, there are very few of such varieties on the market, unlike barley where there are numerous feed varieties, some of which have proven to be good for the production of barley malt. This study aimed to determine the values of the main indicators of wheat quality, micromalting process, and finished malts of new wheat varieties/breeding lines of the Agricultural Institute Osijek, compare them with reference (recommended) values and assess the malt quality.

2. Materials and Methods

Four different new soft winter wheat varieties (henceforth simply referred to as varieties) from the Agricultural Institute Osijek were selected for testing: Indira, OSK. 378/19, OSK. 346/20 and OSK. 353/20. They are characterized as feed/bread varieties. These are *Triticum aestivum* L. (ssp. *vulgare*) red grain (var. *erythrospermum* or var. *lutescens*) varieties obtained from the varietal experiments conducted under the same conditions and at the same location (Osijek 45°32′11.66″ N 18°44′26.84″; 95 m a.s.l.) in the 2018/2019 growing season. At the Osijek location (in a south west region of the Pannonian plain) the climate is predominantly continental with hot summers (sometimes with heat stress in June) and cold/cool winters. The multiannual precipitation and temperature average is 674 mm and 11.2 °C, respectively, with minimum average temperature of 3.24 °C in January and maximum average temperature of 28.1 °C in July. The experimental soil was characterized as an eutric cambisol, with slightly alkaline reaction (pHKCL of 7.43) and 1.80% of organic matter content, and 18.40 mg of P_2O_5 and 22.70 mg of K_2O 100 g^{-1} of soil. Sowing was performed on 15 October 2018. Experimental layout was of a randomized complete block design with four replications. The precedent crop was soybean (*Glycine max*). The sowing rate was 450 seeds/m^2 in eight row plots (the distance between rows was

13.5 cm) of 7 m length and 1.08 m of total width with harvested area of 7.56 m^2 for each plot. Harvesting was done on 8 July 2019. Fertilization was applied during soil preparation (ploughing and harrowing) before sowing (400 kg ha-1 of NPK 7-20-30 and 100 kg ha-1 of UREA 46% N) and during vegetation at Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie (BBCH) 21 and BBCH 31 phenological growth stage [14] (75 kg ha-1 of KAN 27% N, respectively in each stage). Regular third fertilization at BBCH 49/51 was not performed in order to avoid additional influence on grain protein content increase. Sowing rate was 450 seeds m^2 in eight row plots (between rows distance was 13.5 cm) of 7 m length and 1.08 m of total width with harvested area of 7.56 m^2 for each plot. Harvest was done on 8 July 2019. Fertilization was applied before sowing (400 kg ha^{-1} of NPK 7-20-30 and 100 kg ha^{-1} of UREA 46% N) and during vegetation at BBCH 21 and BBCH 31 phenological growth stage (75 kg ha^{-1} of KAN 27% N, respectively in each stage). Fungicide spraying was conducted during vegetation at stages BBCH 31/32 (tebuconazole 167 g L^{-1}, spiroxamine 250 g L^{-1}, triadimenol 43 g L^{-1}); BBCH 47 (prothioconazole 130 g L^{-1}, bixafen 65 g L^{-1}, fluopiram 65 g L^{-1}), BBCH 61 (prothioconazole 125 g L^{-1}, tebuconazole 125 g L^{-1}). Two herbicide and one insecticide treatment were applied to control weeds and insects. Breeding lines/varieties (Indira, OSK. 378/19, OSK. 346/20 and OSK. 353/20) were selected regarding their lower quality properties (protein and gluten content) suggesting potential suitability for malting purposes. Although they are denoted as winter wheat varieties with red colored grain, European Union (EU)/Croatian varieties have different (usually lower) quality parameters than the typical "hard red wheat" found in the USA and Canada. These are also varieties from the assortment that is characterized by a relatively low concentration of soluble N in relation to the total starting N and show excellent values for the viscosity of wort [13,15]. Sampling, cleaning, and finishing of wheat were performed according to the recommended EBC method 3.1 [16]. Samples of processed, untreated grain (5 kg of each variety) were stored in two-ply paper bags and stored in a dry place for two months to overcome post-harvest grain dormancy.

Micromalting (steeping and germination) was performed in a controlled atmosphere incubator (ClimaCell; MMM Medcenter Einrichtungen, München, Germany). In short, 500 g of wheat was soaked in 500 mL of tap water, according to the procedure described in Table 1. Perforated inox containers were emerged into inox contianers with water that was previously placed in the ClimaCell in order to set its temperature to the wanted value (14.5 °C as shown in Table 1). The parameters of all micro-malting phases were adjusted according to the modified, standard MEBAK [17] barley malting scheme (lowering the humidity during germination of wheat to 85%), shown in Table 1. Correction of air humidity to 85% during the dry-steeping phase was performed because wheat absorbs water much faster due to the lack of hull, so the required degree of grain moisture (44.5%) is achieved faster. On the third day of steeping, the grain was left to germinate after the grain moisture was adjusted to 44% (by spraying). In this way, the last day of steeping was also the first day of germination. Malt was kilned (Memmert ventilated oven, UFE 500, Memmert GmbH + Co. KG, Schwabach, Germany), transferred into paper bags and kept at room temperature for three weeks for moisture equilibration. Degermination (removal of roots and malt germs) was done manually, by sifting through a sieve (Vibratory Sieve Shaker AS200 Digit, Retsch GmbH, Haan, Germany). The malt was then stored in a dry place for 30 days to stabilize the enzyme activity and moisture content. Baseline indicators of wheat quality and quality indicators of the micro-malting process itself and finished malt quality were then determined. The analysis of wheat, micromalting process, and finished malt quality was performed according to the EBC and MEBAK analytics [16,17] listed in Table 2. Gluten and gluten index were determined according to ICC standard method No 155 [18] using a Glutomatic 2200 Gluten System and Glutomatic Centrifuge 2015 (Perten/Perkin Elmer, Waltham, MA, USA). Hagberg falling number was determined according to ICC method No 107/1 [19] (Perten FN 1500, Perten/Perkin Elmer) and sedimentation was quantified using Zeleny sedimentation method (ICC No 115/1) [20] (Brabender, Duisburg, Germany).

Table 1. Micromalting scheme of wheat samples.

Day	
1st	Immersion steeping for; 5 h, water t = 14.0 °C Dry steeping for; 19 h, t = 14.5 °C
2nd	Immersion steeping for; 4h, water t = 14.0 °C Dry steeping for 20 h, t = 14.5 °C
3rd *	Immersion steeping for 2 h, water t = 14.0 °C
3rd–7th	Germination was carried out at 14.5 °C during 4 days, air r.H. = 85–87%;
8th	Duration of kilning was 19 h, performed according to standard procedures for pale malt (MEBAK) after last hour of germination, drying finished, malt degermination, measuring and packing in paper bags and stored

* Control of the degree of soaking at the beginning of the third day and every hour of soaking under the water, when it was found that the grain does not tolerate any further soaking under water, moisture content of 44% was adjusted with sparging in germination box (1st day of germination).

Table 2. Used MEBAK and EBC methods for the analysis of wheat and malt.

		Method	
	Unit	**MEBAK®**	**EBC®**
Micromalting		2.5.3.1	
1000 grain weight	g d.wt.		3.4/4.4
Moisture	%		3.2/4.2
Fine extract content	% d. wt.	4.1.4.2.2.	
Saccharification time	min	4.1.4.2.4.	
Clarity of wort	EBC	4.1.4.2.6.	
Filtration time (min)	min	4.1.4.2.5.	
Total proteins f = 6, 25	% d. wt.		4.3.1
Soluble *N*	mg/L		4.9.1
Hartong number VZ 45 °C	%	4.1.4.11.	
Final attenuation of wort	%		4.11
Wort colour	EBC	4.1.4.2.8.2.	
Colour after cooking	EBC	4.1.4.2.9.	
Viscosity	mPas. 8.6%e	4.1.4.4.2.	
Diastatic power	°WK	4.1.4.6.	
α-amylase activity	DU		4.13
Vitreosity	%	4.1.3.5.1	
FAN	mg/100 g malt dry m.		4.10
pH	-	4.1.4.2.7.	

Due to the small number of varieties used, the results are given as an average of three measurements, except for α-amylase activity and total diastatic strength where the expressed result is the average of two measurements.

Data analysis was done using the analysis of variance (ANOVA) and Fisher's least significant difference test (LSD), with a statistical significance set at $p < 0.05$. Statistical analysis was carried out using Statistica 13.1. (TIBCO Software Inc., Palo Alto, CA, USA).

3. Results and Discussion

The aim of this study was to determine the behavior of new varieties of wheat during malting because the data available in the brewing scientific and professional literature refers almost exclusively to Northern European wheat produced under significantly different agroecological and agrotechnical conditions. There were also inevitable limitations in the experiment related to (i) selection of varieties, since we do not have a dedicated wheat malt variety, and (ii) standard micro-malting process (since wheat does not have a hull it absorbs water more easily, resulting in more compact grain pile; this can be reduced by lowering the grain moisture at the beginning of germination). The results of the analysis of the initial quality of wheat are shown in Table 3. The tested wheats are the ones that can be (conditionally) considered as "soft" red, winter wheat with a lower protein content.

Table 3. Quality characteristics of the used wheat varieties (harvest 2019).

Variety	Method		INDIRA	OSK. 378/19	OSK. 346/20	OSK. 353/20
Physical analysis:	MEBAK	EBC				
Grading I. class/above 2.5 mm (%)	2.3.1		93.4 ^{b}	91.2 ^{d}	91.4 ^{c}	95.1 ^{a}
Thousand grain weight (g dry wt.)	2.3.2		44.59 ^{a}	41.95 ^{c}	39.17 ^{d}	43.8 ^{b}
Filth (%)	2.2.5		1.25 ^{b}	1.20 ^{b}	1.85 ^{a}	1.10 ^{c}
Average vitreosity (%)	2.3.4.		31 ^{b}	35 ^{a}	28 ^{c}	18 ^{d}
Physiological analysis:						
Germinative energy (3 days)	2.4.2.1		98.0 ^{a}	97.0 ^{b}	95.0 ^{c}	97.5 ^{b}
Germinative energy (5 days)			99.4 ^{a}	99.0 ^{a}	97.5 ^{b}	99.0 ^{a}
Chemical analysis:						
Moisture content of grain (%)	2.5.1		11.82 ^{b}	11.28 ^{c}	12.66 ^{a}	11.87 ^{b}
Total proteins (% dry wt.) F = 5.7		3.3.1	12.35 ^{c}	12.16^{c}	13.55 ^{a}	12.75 ^{b}
Sedimentation value (ml)		ICC 115/1	36 ^{a}	34 ^{c}	34 ^{c}	35 ^{b}
Gluten (%)		ICC 107/1	24.5 ^{c}	24.8 ^{c}	28.0 ^{a}	26.6 ^{b}
Gluten index		ICC 107/1	99 ^{a}	98 ^{b}	92 ^{d}	95 ^{c}
Falling number (s)		ICC 155	312 ^{c}	301 ^{d}	330 ^{a}	322 ^{b}

Values are means obtained after three measurements. Values displayed in the same row and tagged with different letters ($^{a–d}$) are significantly different (p < 0.05).

Since wheat is in Croatia almost exclusively selected and bred for the needs of the baking industry, properties (un)desirable for malting are yet to be etablished for malting and brewing wheat. The results of the initial analyzes of wheat (Table 3) showed satisfactory values for the 1000 grain weight. Elevated vitreousity values were found to be almost completely transient, and thus not problematic for malt quality. Germinative energy, both after 3 and 5 days, showed very good results and according to this easy malting with acceptable losses should take place. Total proteins exceeded the recommended values, especially for varieties OSK. 346/20 and OSK. 353/20. Recent tests of malt quality of domestic assortment have shown that the increased concentration of total proteins does not lead to unacceptable (too high) values for soluble proteins [21]. Jin et al. [22] reported that appropriate processing conditions could compensate for the adverse effects of a high wheat protein content, in other words prolongation of germination time wheat varieties containing 16% of proteins in the end gave good quality malt. However, it should be noted that there is no correlation among total proteins, soluble proteins, and colloidal instability precursor proteins (haze active proteins).

Although opinions on protein content in wheat differ, where some authors [23,24] claim that soft wheat varieties (mealy or floury endosperm and a protein content of up to 11%) are more suitable for brewing and on the other hand, other scholars [25,26] encourage the use hard wheat varieties with high protein content that presumably contain more haze-active proteins of high molecular weight and are thus better for the production of hazy white beer. However, recent research gave different result where, although in absolute values the concentration of total proteins is within satisfactory limits, it can result in increased levels of proteins in wort [27]. The results of malt analysis in Table 4 and of the analysis of the micro-malting process are shown in Table 5. In Table 5 germination process losses were followed and all varieties showed higher values than recommended for total losses (<10%), as well as in the ratio of germ losses to respiration losses ($^2/_3$:$^1/_3$). This usually means that higher amounts of energy have been employed for germination (more sugars have been spent) for germination than it is desirable. In practice this means less fermentable sugars for yeast during fermentation. The values for total proteins in finished malts (except OSK. 346/20) were very good, approximately similar to the values obtained for barley malts from domestic barley varieties [28–30]. But it should be noted that the proteins in wheat are usually higher than in barley malt, and besides they are of a different composition than barley [15]. This different protein composition is responsible for the fact that significantly more macromolecular proteins pass into the wort (almost twice as much as for barley malt), and it is important for the sensory evaluation of beer that its share is not too high. It is strongly positively correlated with total soluble N [13,31,32]. Soluble nitrogen is that part of the compounds with nitrogen which, under the conditions of comminution, passes into solution. The increased protein content in the grain affects the increase of soluble nitrogen because they represent a substrate for proteolysis, i.e., the law applies that the concentration of the product increases with increasing concentration of the substrate. The values of the Hartong number or relative extract at 45 °C (VZ 45 °C) were within acceptable limits. VZ 45 °C is determined as the ratio of the extract obtained after isothermal grinding for one hour and the extract of finely ground malt. In light malt, it is a measure of the activity of enzymes that work successfully at this temperature (45 °C), and these are mainly proteases, (most of which have the optimum effect at this temperature). Therefore, VZ values of 45 °C are in the best (positive) correlation with other indicators of proteolysis, i.e., with the amount of soluble nitrogen, Kolbach's number, and FAN. Furthermore, it is a real measure of the activity of all other enzymes that have an optimum at about 45 °C, so it is also a very good indicator of carboxypeptidase activity. The values for the viscosity of the congress wort were excellent. This can be attributed to the lower concentration of total arabinoxylans, and the reduced proportion of solubles in total arabinoxylans. This agrees with previous research on the quality of the domestic wheat assortment. Arabinoxylan (pentosans) is the most important factor influencing viscosity [33]. Interestingly, the share of soluble protein concentrations in total proteins is also in the examined assortment. This may be why the malt of satisfactory quality can also be obtained from red, hard varieties [34]. The content of free-amino nitrogen (FAN) is also relatively lower (below the recommended values) which is not necessarily bad for the values of the final degree of overturning because excessive protein breakdown can burden amino acids that are not useful and may even be harmful to yeast (glycine, proline, hydroxyproline). About 70% of total FAN is released in the grain during malting and 25–

30% during mashing [27]. α-Amylase activity in all investigated varieties was at the lower acceptable limit for light brewing malt. A common step in assessing brewing quality is to determine in which qualitative malting group wheat belongs to. If, for example, it belongs to the 2nd qualitative group, then the malting process should be optimized according to that fact. That is, the malting process should be set to suppress the excessive proteolysis with minimal negative impact on other quality indicators. Within each qualitative group, efforts will be made to determine varieties that, in addition to the basic requirement related to soluble protein content and malt viscosity, have values of other quality indicators as close as recommended. In example, if two varieties have soluble protein content below 760 mg/L then the one with a FAN share >16% in soluble *N* will be considered more suitable [35].

Table 4. Results of malt analysis.

Quality Indicator	Variety				Recommended Value
	INDIRA	OSK. 378/19	OSK. 346/20	OSK. 353/20	
Moisture (%)	5.87 ^{b}	5.99 ^{a}	5.91 ^{a}	5.59 ^{c}	-
1000 grain weight (g d.wt.)	41.24 ^{a}	38.02 ^{c}	37.3 ^{d}	40.1 ^{b}	-
Vitreosity (%)	8 ^{a}	3 ^{c}	2 ^{d}	4 ^{b}	5–10
Total proteins (% d.wt.) f = 6.25	11.6 ^{b}	11.2 ^{b}	12.5 ^{a}	12.0 ^{a}	11–11.5
Soluble *N* (mg/L)	568.3 ^{b}	542.5 ^{c}	672.7 ^{a}	562.3 ^{c}	555–700
Fine extract content (% d.wt.)	82.9 ^{ab}	83.1 ^{a}	83.0 ^{a}	82.5 ^{b}	>83
Saccharification time (min)	10–15	10–15	10–15	10–15	10–15
Clarity of wort (EBC u.)	3.3 ^{a}	3.0 ^{a}	3.4 ^{a}	3.1 ^{a}	-
Wort colour (EBC u.)	3.0 ^{a}	3.4 ^{a}	2.6 ^{b}	2.8 ^{b}	3–5
Colour after cooking	4.2 ^{b}	4.8 ^{a}	4.7 ^{a}	4.2 ^{b}	-
Filtration time (min)	55 ^{a}	55 ^{a}	54 ^{b}	55 ^{a}	<60
pH	5.7 ^{b}	5.8 ^{ab}	5.8 ^{ab}	5.9 ^{a}	5.9–6.1
Viscosity (mPas. 8.6%e)	1.507 ^{c}	1.505 ^{c}	1.581 ^{a}	1.556 ^{b}	1.5–1.8
Hartong number VZ 45 °C (%)	36.8 ^{a}	36.7 ^{a}	34.7 ^{b}	32.1 ^{c}	>33
Diastatic power (°WK)	265 ^{c}	252 ^{d}	271 ^{b}	285 ^{a}	250–420
α-amylase activity(DU)	51 ^{b}	46 ^{c}	46 ^{c}	55 ^{a}	40–60
Final attenuation of wort(%)	82.5 ^{b}	83.0 ^{a}	81.8 ^{c}	83.0 ^{a}	>82
FAN (mg/100 g dry wt.)	116 ^{b}	110 ^{c}	110 ^{c}	143 ^{a}	<180

Values are means obtained after three measurements. Values displayed in the same row and tagged with different letters ($^{a–d}$) are significantly different ($p < 0.05$).

Table 5. Results of wheat germination properties.

	Variety				
	INDIRA	**OSK. 378/19**	**OSK. 346/20**	**OSK. 353/20**	**Recommended Value**
Moisture after 48 h (%)	44.5 a	44.5 a	44.5 a	44.5 a	-
Moisture at the beggining of germination phase (%)	42.9 b	42.6 b	43.3 b	44.0 a	<44.5
Moisture of green malt (%)	45.3 b	45.8 b	45.0 c	46.2 a	-
Moisture of malt (%)	5.30 ab	5.41 a	5.09 c	5.11 bc	4.8–5.5
Total losses (g/d.wt.)	13.8 a	12.1 c	11.7 c	12.6 b	<10
Respiration losses (g/d.wt.)	5.9 a	5.0 b	5.2 b	5.4 ab	-
Germination losses (g/d. wt.)	7.9 a	7.1 b	6.5 c	7.2 b	-

Values are means obtained after three measurements. Values displayed in the same row and tagged with different letters (a–c are significantly different ($p < 0.05$).

4. Conclusions

According to this research, the tested wheat varieties meet the criteria for light malt and can be classified in the II malt quality group according to [1] since the majority of examined quality indicators showed values within the limits recommended for light wheat malt. It can be said that the obtained results are very good considering that these are varieties that are not dedicated as malt varieties, nor in their selection process attention was exclusively paid to malt quality criteria. The desired sensory characteristics of beer limit the possibility of interventions in the malting process, therefore the cultivation of wheat intended for malting should engage breeders to pay attention to increase the activity of α-amylase, and growers to apply the appropriate agro-technical measures.

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