Modeling and Optimization of the Process of Hopped Beer Wort with Topinambur Additives

Firuza Rustambekova	PhD, Associate Professor, Tashkent Chemical-Technological Institute, Uzbekistan, Tashkent E-mail: frustambek@bk.ru
Miraziz Mirkhuzhaev	Master student, Tashkent Chemical-Technological Institute, Uzbekistan, Tashkent E-mail: rustambekova83@bk.ru
Sharoffiddin Eshmetov	Master student, Tashkent Chemical-Technological Institute, Uzbekistan, Tashkent E-mail: rustambekova83@bk.ru

ABSTRACT

In this work, we have studied the color of young beer with the addition of Jerusalem artichoke additives, in which it increases, and more than 10% replacement of malt with Jerusalem artichoke can inhibit the fermentation process. It was determined that the color within the standard is maintained with the addition of up to 10% Jerusalem artichoke additives, and this dosage is considered the maximum possible in the production of light beers.

Keywords: Jerusalem artichoke, beer color, mashing, fermentation, brewing beer wort, modeling, optimization, hopped beer wort.

Introduction

In most countries of the world, including Uzbekistan, there is a steady upward trend in the production and consumption of beverages. In recent years, consumer demand for low alcohol drinks and beer has been increasing. Drinks are of particular importance and have a very positive effect on the human body. This is primarily due to the nutritional and biological value of these products. They serve as sources of carbohydrates, organic acids, minerals, and other biologically active components. From the consumer point of view, organoleptic properties and the ability of the drink to quench thirst are of great importance. Obtaining beer by replacing part of the malt with Jerusalem artichoke tubers or with powder, juice, concentrate from Jerusalem artichoke is a new direction in the production of beer. There are isolated works that are devoted to this area. The obtained samples of beer wort and beer were compared with the data calculated by modeling and optimization of the process of hopped beer wort with the addition of Jerusalem artichoke and young beer. Under the conditions of non-uniform planning of experiments, data were obtained on the mathematical model of the process of hopped beer wort with the addition of Jerusalem artichoke and young beer.

At this time in Germany, there is practically no beer with unmalted raw materials, since they have adopted a law on the purity of beer for 500 years. [1]. According to Russian scientists, in the production of beer, water extracts from the tuberous or aerial parts of the plant or dry powders with a moisture content of no more than 14% obtained from various parts of Jerusalem artichoke and their extracts are used as additives from Jerusalem artichoke. They are introduced with malt when mashing it, or when boiling the wort with hops, or at the stages of fermentation or additional fermentation, or at the end of fermentation before filtering the finished beer. In the production of beer using Jerusalem artichoke, an additive in the form of aqueous extracts or dry powders is added based on a ratio with malt from 1/100 to 1/6 based on dry weight. The proposed solution makes it possible to obtain new varieties of beer with increased biological value due to the enrichment of the product with inulin, trace elements and other biologically active components contained in additives based on Jerusalem artichoke, which are used as an additional plant component in beer production along with the main components of malt and hops [2; 3; 4.].

Main Part

Temperature and time modes of technological processes are generally accepted due to standard components - malt and hops and depend more on the equipment and technological capacities of beer production and do not affect the essence of the proposed method. Also, the essence of the proposed method is not affected by the options for producing light and dark beers of different persistence, depending on the density of the prepared wort (the amount of malt used and its preparation), filtration (separation) and pasteurization options.

Jerusalem artichoke supplements are known to contain fructose and small amounts of semi-fruits. It has been determined that the preparation of beer wort with the addition of Jerusalem artichoke additives has a positive effect on the quality of beer. Beer wort obtained by traditional technology at the “Raupxon” brewery was taken as a sample. To determine the maximum possible dose of additives that would not affect the organoleptic and physicochemical properties of the finished beer, a ratio of 3% to 15% was studied. The results are presented in tab. 1, as well as statistical data in Fig. 1,2,3.

Table 1

The chemical composition of hopped wort with Jerusalem artichoke additives

Indicator names	Percentage of Jerusalem artichoke juice in hopped wort,%					Control 100% malt
	3	5	7	10	15	
Mass fraction of DM,%	11,0	11,2	11,5	12,0	13,5	11,0
Reducing substances mg / cm^3	27,0	27,2	27,2	27,2	27,3	27,4
Reducing substances mg / cm^3	16	16,5	17	18	24	15
Color of hopped wort, cm^3 0.1 N. solution I_2 / 100 cm^3	3,4	3,5	3,6	3,7	3,8	2,5
Titratable acidity, cm^3 1n. NaOH solution / 100 cm^3	4,3	4,4	4,6	4,7	4,8	4,2

Analysis of the obtained samples showed that the chemical composition of the wort in all cases did not differ from the control wort, the color of the wort increased in proportion to the added amount of Jerusalem artichoke additives. This is explained by the fact that fructose is more active in the formation of melanoidin than maltose.

Under the conditions of non-uniform planning of experiments, a mathematical model of the process of hopped beer wort with the addition of Jerusalem artichoke and young beer was obtained. Experimental data on hopped beer wort with Jerusalem artichoke and young beer with a control 100% malt are shown in Tab. 1. According to the table, we determine the mathematical expectation, the standard deviation [5; 6; 7.] mass fraction of dry and reducing substances, α-amine nitrogen, color of hopped wort, titratable acidity.

One of the indicators affecting the quality of beer is the mass fraction of dry substances. The conclusion about the completeness of the nesting of Jerusalem artichoke supplements is divided on the basis of comparison, the DM content obtained as a result of the control analysis, with a minimum content. Mass fraction of DM, %. The dry matter content in beer wort ranges from 11 to 20% and depends on the type of beer produced. Since the studied beer wort is prepared according to the classical method for light beer, these indicators are considered good.

The mathematical expectation is determined for the control sample.

$$mDM = \frac{\sum_{i-1} mDMi}{n_э} = \frac{11{,}2 + 11{,}13 + 11{,}6 + 11{,}27 + 11{,}24}{5} = 11{,}20 \quad (1.1.)$$

The mathematical expectation is determined for the mass fraction of DM.

$$mDM = \frac{\sum_{i-1} mDMi}{n_э} = \frac{11{,}2 + 11{,}5 + 11{,}6 + 11{,}7 + 11{,}9}{5} = 11{,}58 \quad (1.2.)$$

Root mean square deviation

$$\sigma CB = \sqrt{\frac{\Sigma\Delta mCB^2}{n}} = \sqrt{\frac{\Sigma\Delta 0^2 + 2{,}67^2 + 3{,}57^2 + 4{,}46^2 + 6{,}25^2}{5}} = \sqrt{\frac{\Sigma\Delta 78{,}66}{5}} = \sqrt{15{,}73} = 3{,}96 \quad (1.3)$$

It was shown that when 5-30% of Jerusalem artichoke additives were introduced into the samples of beer wort, the amount of reducing substances and the final degree of fermentation increased in them. All samples with Jerusalem artichoke additives fermented well, as well as the control one. The increase in reducing substances had a positive effect on the fermentation of the beer wort.

The mathematical expectation is determined for the control sample RV.

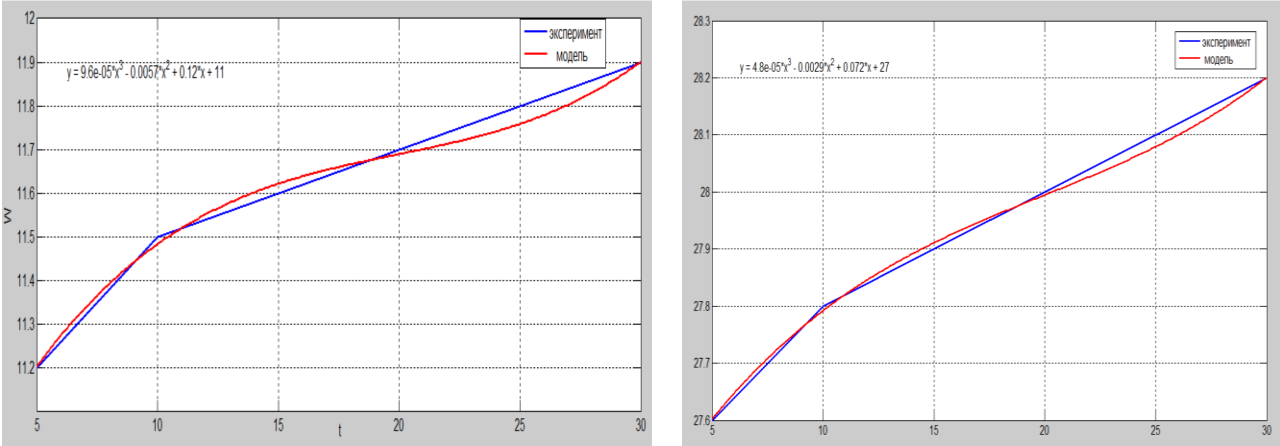
$$mPB = \frac{\sum_{i-1} mPBi}{n_э} = 27{,}4 \quad (1.4.)$$

The mathematical expectation is determined for the RV

$$mPB = \frac{\sum_{i-1} mPBi}{n_э} = \frac{27{,}6 + 27{,}8 + 27{,}9 + 28 + 28{,}2}{5} = 27{,}9 \quad (1.5.)$$

Root mean square deviation

$$\sigma PB = \sqrt{\frac{\Sigma\Delta mW^2}{n}} = \sqrt{\frac{\Sigma\Delta 0{,}7^2 + 1{,}4^2 + 1{,}8^2 + 2{,}1^2 + 2{,}9^2}{5}} = 3{,}7 \quad (1.6.)$$



>> t=[5 10 15 20 30]; >> W=[11.2 11.5 11.6 11.7 11.9]; >>plot (t,W)
*Equations:y = 9.6e-05*x³ - 0.0057*x² + 0.12*x + 11* y = p1*x^3 + p2*x^2 +p3*x + p4
coefficient: p1 = 9.5597e-05; p2 = -0.0057035; p3 = 0.12473; p4 = 10.711
error rate = 0.029369

>> t=[5 10 15 20 30]; >> W=[27.6 27.8 27.9 28 28.2]; >> plot (t,W)
Equations:y = p1*x^3 + p2*x^2 +p3*x + p4
coefficient: p1 = 4.7799e-05;
p2 = -0.0028518; p3 = 0.072363;p4 = 27.306.
error rate = 0.014684

Fig. 1. Statistical model of the mass fraction of dry substances (left) and reducing substances (right) of hopped wort, prepared with the addition of Jerusalem artichoke additives

Amine nitrogen affects the fermentation process of the wort, it is mainly required by the yeast during the main fermentation. When added with 10% Jerusalem artichoke supplements, it has a very good effect on AA, which is twice the control sample. When adding 5% of Jerusalem artichoke additives, α-amine nitrogen increases by 7 mg / 100 cm³, at 15%; 20%; 30%, which is very good for dark beers, increases by 18; 19; 21 mg/100 sm³.

The mathematical expectation is determined for the control sample AN.

$$mAN = \frac{\sum_{i-1} mANi}{n_э} = 14 \quad (1.7.)$$

We determine the mathematical expectation for AN.

$$mAN = \frac{\sum_{i-1} mANi}{n_э} = \frac{2,1+3,1+3,2+3,3+3,5}{5} = 12,4 \quad (1.8.)$$

Root mean square deviation (1.9.)

$$\sigma AA = \sqrt{\frac{\Sigma \Delta mAN^2}{n}} = \sqrt{\frac{15^2+22^2+22,8^2+23,5^2+25^2}{5}} = 21,9$$

The data of the obtained samples on the color of the hopped wort in all variants differs little from the control sample. As you can see from the table. 1. The color of the hopped wort increased in proportion to the amount of Jerusalem artichoke added. This is due to the fact that fructose more actively than maltose enters into the melanoidin formation reaction.

The mathematical expectation is determined for the control sample DSP

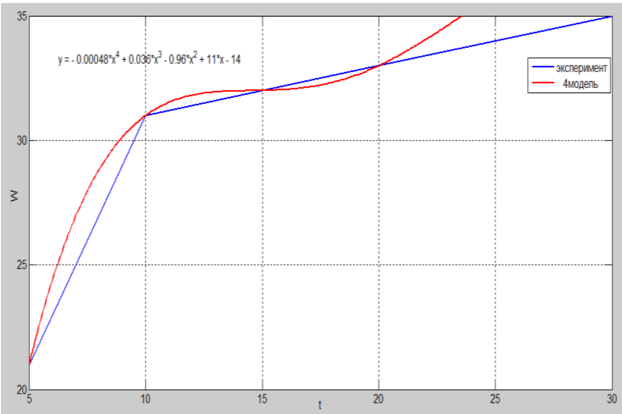
$$m\text{ЦЦО} = \frac{\sum_{i-1} m.DSPi}{n_э} = 2{,}9 \quad (1.10.)$$

We determine the mathematical expectation for DSP.

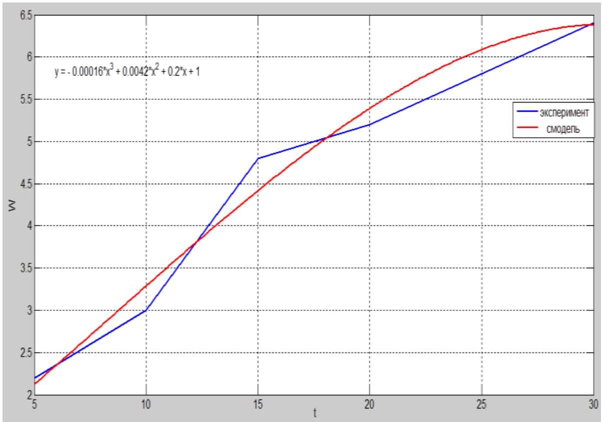
$$m\text{ЦЦО} = \frac{\sum_{i-1} m.\text{ЦОС}i}{n_э} = \frac{2{,}2 + 3{,}0 + 4{,}8 + 5{,}2 + 6{,}4}{5} = 4{,}32 \quad (1.11.)$$

Root mean square deviation.

$$\text{ЦОС}\sigma_W = \sqrt{\frac{\Sigma \Delta W^2}{(W_{max} - W_{min})^2 \cdot n}} = \sqrt{\frac{2{,}4^2 + 3{,}4^2 + 6{,}5^2 + 7{,}9^2 + 2{,}0^2}{5}} = 7{,}2 \quad (1.12.)$$



>> t=[5 10 15 20 30]; >> W=[21 31 32 33 35]; >> plot (t,W). y = p1*x^4 + p2*x^3 +p3*x^2 + p4*x +p5. coefficient: p1 = -0.00048; p2 = 0.036; p3 = -0.96; p4 = 11; p5 = -14.2; error rate = 1.3538e-13



>> t=[5 10 15 20 30]; >> W=[2.2 3 4.8 5.2 6.4]; >> plot (t,W). y = p1*x^4 + p2*x^3 +p3*x^2 + p4*x +p5. coefficient: p1 = 0.00018933; p2 = -0.012667; p3 = 0.28167; p4 = -2.2033; p5= 7.64 error rate = 3.813e-14

Fig. 2. Statistical model of α-amino nitrogen (left) and color (right) of hopped wort prepared with the addition of Jerusalem artichoke additives.

Titratable acidity also, in all ratios of Jerusalem artichoke supplements, does not differ significantly from the control sample. According to the data from the table, the titratable acidity in the 5% ratio is almost the same, 10% and 15% are the same, however, compared to 20% and 30%, 0.3 and 0.6 cm^3 are hung, which is explained by the large% replacement of malt with Jerusalem artichoke additives. Acidity has a very beneficial effect on the taste of beer and on its resistance to biological contamination and biological stability.

The mathematical expectation is determined for the control sample titratable acidity

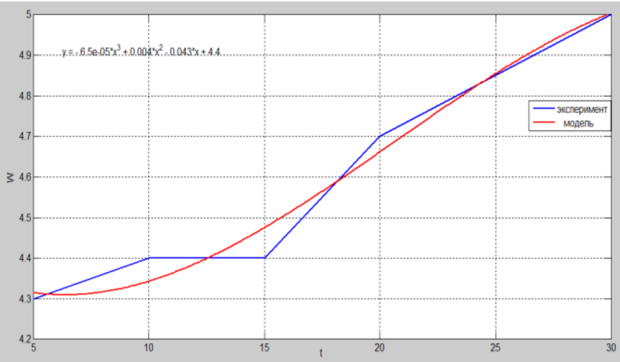
$$mTK = \frac{\sum_{i-1} m.TKi}{n_э} = 4{,}4 \quad (1.13.)$$

The mathematical expectation is determined for the titratable acidity

$$mTK = \frac{\sum\limits_{i-1} m.TKi}{n_э} = \frac{4{,}3+4{,}4+4{,}4+4{,}7+5}{5} = 4{,}56 \quad (1.14.)$$

Root mean square deviation

$$\sigma TK = \sqrt{\frac{\Sigma \Delta mTK^2}{n}} = \sqrt{\frac{2{,}27^2+0^2+0^2 6{,}8^2+13{,}63^2}{5}} = 6{,}8 \quad (1.15.)$$



>> t=[5 10 15 20 30]; >> W=[4.3 4.4 4.4 4.7 5]; >> plot (t,W). y = p1*x^3 + p2*x^2 +p3*x + p4
coefficient: p1 = -6.5409e-05; p2 = 0.0040377; p3 = -0.043459; p4 = 4.4396.
error rate = 0.10279

Fig. 3. Statistical model of the titratable acidity of hopped wort prepared with the addition of Jerusalem artichoke additives

Conclusion

In summary, it is determined that the color within the standard is maintained with the addition of up to 10% Jerusalem artichoke additives, and this dosage is considered the maximum possible in the production of light beers. Temperature and time modes of technological processes are generally accepted due to standard components - malt and hops and depend more on the equipment and technological capacities of beer production and do not affect the essence of the proposed method.

References

1. Закон «О чистоте пива». http://www.pivnovbar.ru
2. Меледина, Т.В. Сырье и вспомогательные материалы в пивоварении /Т.В. Меледина. – СПб.: Профессия, 2003. – 304 с.
3. Kunz V. Technology of malt and beer/V. Kuntse G. M-SPb.: Professiya, 2003. – 912 p.
4. Патент Российской Федерации № 2149 894 «Способ производства пива с использованием топинамбураhttps://findpatent.ru/patent/, 2012-2020.
5. Ermolaeva G. A. Reference book lab employee brewing company. SPb.: Professiya, 2004. P. 446.
6. Гартман Т.Н. Основы компьютерного моделирования химико-технологических процессов: учеб. пособие для вузов / Т.Н. Гартман, Д.В. Клушин. – М.: ИЦК «Академкнига», 2006. –416 с.
7. Дьяконов, Владимир Matlab. Анализ, идентификация и моделирование систем. Специальный справочник / Владимир Дьяконов, Владимир Круглов. - М.: СПб: Питер, 2002. - 448 стр.