COMPARISON OF THE HYDROCOLLOIDS APPLICATION EFFICIENCY FOR STABILIZING THE FOAM OF BEER

Ruslana Kosiv[1]

[1]Department of Organic Products Technology, Lviv Polytechnic National University, Ukraine, Lviv
E-mail: ruslana.b.kosiv@lpnu.ua
ORCID: http://orcid.org/0000-0003-4421-5735

Kosiv, R. (2021). Comparison of the hydrocolloids application efficiency for stabilizing the foam of beer. ScienceRise, 6, 25–30. doi: http://doi.org/10.21303/2313-8416.2021.002232

ARTICLE INFO

Article history:
Received date 02.11.2021
Accepted date 04.12.2021
Published date 30.12.2021

Section:
Food production

DOI

10.21303/2313-8416.2021.002232

KEYWORDS

high gravity brewing
beer foam
hydrocolloids
polysaccharides
pectin
carboxymethyl cellulose
xanthan gum
guar gum

ABSTRACT

Subject of research: technology of high gravity brewing, developed to improve production efficiency and reduce energy consumption. This technology has a wide range of benefits, from improving process economics to reducing environmental impact.

Investigated problem: despite the presence of significant advantages, there are a number of problems in the technology of high gravity brewing that need to be solved. The main problem is to reduce the foam stability of the resulting beer, which, together with the appearance, aroma and taste, is the most important attributes of the quality of the beverage for the consumer. The stability and texture of the foam depend, among other things, on the quality of grain and hop raw materials, and the course of technological processes. Elevated levels of key malt proteins (LTP1, Z4 and Z7) and hop α-acids have a positive effect on foam quality. Yeast protease A has a negative effect. Yeast secretes this enzyme to a greater extent during fermentation of high gravity wort, which may be one of the reasons for the decrease in foam stability in high gravity brewing.

High molecular weight α- and β-glucans with hydrophilic properties can play an important role in foam stabilization. They increase the viscosity of the liquid, slow down its drainage from the foam segments and thereby increase the foam retention.

Main scientific results: the effect of hydrocolloids (highly methoxylated pectin, carboxymethyl cellulose, xanthan gum, guar gum, a mixture of xanthan and guar gum) on foam performance and beer filtration rate was investigated. The advantages of pectin as an additive allowing to stabilize beer foam, in particular, in high gravity – brewing, have been established. The recommended dosage of the additive is 0.4–1 g/hl. Highly methoxylated pectin is a good alternative to the currently widespread use of propylene glycol alginate.

The area of practical implementation of the research results: brewing companies.

Innovative technological product: highly methoxylated pectin as a stabilizing additive for beer foam.

Scope of application of the innovative technological product: the use of highly methoxylated pectin as additives that stabilize beer foam, in particular in high gravity brewing.

1. Introduction

One of the most important attributes of beer quality for the consumer are sensory characteristics – appearance, aroma, taste, foaminess. There are many components involved in creating the taste and aroma of beer. All flavoring components work together to create a sensory profile of the product in conjunction with the aroma [1].

The formation of the sensory profile of beer is determined by numerous factors, the main of which are the quality of raw materials (malt, hop preparations), the characteristics of the yeast used, and technological parameters that significantly affect the course of biochemical transformations. In particular, a difference was established in the sensory profiles of two groups of beer – craft and industrial. At the same time, the foam stability of craft beer was significantly higher than that of industrial beer [2].

High gravity and ultra-high gravity brewing (the original wort gravity is 13–18 °*P* and more than 18 °*P*, respectively) has a wide range of advantages, from improving the efficiency of the process to reducing the impact on the environment [3]. However, there is a trade-off between production efficiency and the quality of the resulting product. The main reason for the change in the taste profile of beer is the accumulation of a larger amount of esters, especially acetate (ethyl acetate, isoamyl acetate), which affect the beer aroma, creating a fruity smell similar to a solvent [4], as well as an increase in the content of higher alcohols, giving the beer an alcoholic, guilty smell [1, 5].

However, the main problem in high gravity brewing is the decrease in foam stability, which can be influenced by many factors, including protein content and the presence of lipids and proteases [6].

Relevance of the topic. The main consumer characteristics of beer – foaminess and head retention – depend on its chemical composition.

Foam as a dispersed system consists of bubbles of carbon dioxide (dispersed phase) surrounded by a thin layer of surfactants with low surface tension. The shells around carbon dioxide, forming a foam, bonded to each other in a cellular structure, they contain chemicals that are present in the beer (dispersion medium), but in completely different proportions. The foam is dominated by bitter α-acids in an amount about five times higher than their content in beer, the content of nitrogen is 19 % more, iron ions – almost twice, pentosans, dextrins, rubber-substances and other components of beer are found [7].

The foam stability of beer depends on the aggregate stability of this dispersed system. The stability and texture of beer foam depend, among other things, on the quality of grain and hop raw materials, and the course of technological processes. In particular, elevated levels of key malt proteins and hop α-acids tend to have a positive effect on foam quality, while excessive levels of lipids, modified protein and ethanol tend to reduce foam quality.

Among the components of beer foam, protein substances are well studied, which, together with bitter acids, play a major role in the process of foam formation. In work [8] it was found that polypeptides obtained from barley proteins – albumin and hordein, can form the potential of beer foam. Iso-α-acids increase the foam stability of these proteins, while a proportional increase was observed for non-denatured proteins.

In works [9–11] it was found that the proteins LTP1, as well as Z4 and Z7, which enter the beer from raw malt, have the greatest effect on beer foam, therefore the use of malt with an optimal content of the corresponding components should improve the foam stability. However, significant differences in the content of total and hydrophobic polypeptides and β-glucan among the studied batches of malt [12] did not affect the stability of beer foam. Thus, there is little room for improving head stability through malt selection in beer production. The use of increased amounts of unsweetened grain raw materials and carbohydrate additives (including glucose-fructose or maltose syrups) reduces the content of foaming proteins in beer, which can adversely affect its foamy properties.

It should be noted the negative effect of yeast protease A on foam stability, and the amount of enzyme secreted by the yeast depends on the strain used. During fermentation, the indicator gradually increases and by the end of fermentation, when the nutrients of the medium dry up, it reaches its maximum value. At the same time, yeast secrete protease A to a greater extent during fermentation of high gravity wort, which may be one of the reasons for the decrease in foam stability in high gravity brewing [7]. Yeast proteinase A hydrolyzes both classes of proteins (albumins and hordeins) and reduces their ability to form persistent foams [8].

Another group of substances that determine the properties of the foam, although they are surface active, are not able to participate in the formation of elastic shells of gas bubbles. It is possible to talk about the bitter substances of hops, melanoidins and polyphenols, which, due to complexation with proteins, strengthen the formed film. Tannins and anthocyanogens are capable of causing coagulation at certain stages of oxidation and condensation and, thus, deterioration of the foam quality [7].

Ethanol, which reduces surface tension, can improve foam retention up to a certain level (mass fraction in beer up to 5–6 %), but at higher concentrations it leads to deterioration of foam formation [13].

Recently, work has been actively carried out aimed at researching methods for stabilizing beer foam using various additives. In particular, the influence of sorption materials was studied, the most promising among which were activated carbons, Florisil and polytetrafluoroethylene [14].

It should be noted that high molecular weight α- and β-glucans with hydrophilic properties play an important role in foam stabilization. They increase the viscosity of the liquid, slow down its drainage from the foam segments and thereby increase the foam retention [13]. In [15], the effect of hydrocolloids on foam stability was studied. The best effect is achieved using propylene glycol alginate, pectin and harsh wood gum. A beer foam stabilizer, a pectin preparation in the form of a hop extract, has been developed [16].

Currently, in the brewing industry, to stabilize beer foam, propylene glycol alginate (PGA) preparations are used at a dosage of 3–10 g/hl of the beverage, which are recommended to be added after filtering beer in the form of a 1–2 % solution in water or beer and filtered again after stirring [13].

The aim of research was to establish the feasibility of a method for stabilizing beer foam, in particular, obtained by the technology of high gravity brewing, using hydrocolloids of a polysaccharide nature.

2. Materials and methods of research

There are used:

– preparations of hydrocolloids: highly methoxylated pectin (MP), sodium carboxymethyl cellulose (SC), xanthan gum, guar gum, a mixture of xanthan and guar gum, which are selected based on their functionality, application characteristics and availability in the domestic food market; characteristics of additives are presented in **Table 1;**

– hopped beer wort prepared according to the technology of high gravity brewing from light barley malt (70 %) and fat-free corn flour (30 %) in a single decoction method with the following indicators: original gravity of wort 16 °P, final degree of fermentation 82,5 % (provided by a local brewery for research);

– wort with a gravity of 12 °P, which was prepared by diluting 16 °P wort with prepared water, was used as a matrix for determining the beer foam indicators;

– light beer filtered at the stage of preparation for bottling, prepared according to the technology of high gravity brewing from wort with a gravity of 16 °P and conditioned to the indicators corresponding to 12°P beer, in particular, the ethanol content is not less than 3.4 % (v/v), the CO_2 content is not less than 0.33 % (w/w) (provided by the local brewery for research).

Table 1

Characteristics of hydrocolloids [17]

Characteristics	Pectin MM	SC	Xanthan gum	Guar gum
E-code	E440	E466	E415	E412
Origin	fruit extract	cellulose	fermentation product	seed extract
Chemical composition	α-D-galacturonic acid, partially esterified with methanol	cellulose ether and Na salt of glycollate acid (2-hydroxy-ethanic acid)	β-D-glucose, α-D-manose, α-D-glucuronic acid 2: 2: 1, acetate groups (up to 4.7 %)	neutral galactomannan, D-mannose 64–67 %, D-galactose 33–36 %
Low temperature water solubility	good	high	high	good
Solution viscosity	low to high	low to high	very high	high
Thickening effect	short	from low to high	high	high
PH stability	2.5–4.5	3–10	2–10	2–10
Stabilization of emulsions	high[1]	maintenance of emulsifiers	high	average
Dosage level	0.5–5 %	0.05–0.5 %	0.05–0.5 %	0.05–0.5 %
Price, USD/kg [18]	12–15	3–6	3–6	1–3

Note: [1] – for acetylated pectins

Study of the head retention of beer. Foaming indicators are a complex parameter of beer quality, which includes several aspects, in particular: foam stability, its appearance, structure, resistance to negative influences. The appearance and structure of the foam also depend on the way it is formed. For these reasons, there is no universal method for measuring foaming indicators [19].

Beer foam values were determined by the Matrix Foaming Potential Measurement (MFP) method. MFP is a measure of the ability of any matrix to form and maintain stable foam. The matrix can be any product from malt wort to beer at any stage of production [20].

In our studies, the matrix was samples of beer wort and beer without additives and with additives of hydrocolloids. Foam for MFP measurement was prepared by mixing degassed samples using a mixer with a variable speed of rotation of 900 rpm. After that, a visual measurement of the foam height (mm) and the time required for the appearance of an island of liquid with a diameter of 5 mm in the foam were carried out. Based on the results obtained, the changes in the foam height and foam resistance (in units) were calculated as the ratio of the height and foam stability of the test sample (with a certain amount of hydrocolloid additive) to the corresponding indicators of the control sample (without additive).

Study of the filtration rate of beer. The filtration capacity of beer is influenced by the filtration technology, as well as the composition of the beer. Over the years, various approaches have been proposed to measure the filtration performance of beer in the laboratory [21]. However, when separating suspensions obtained under different conditions, one can compare their filtration rates [22].

The change in the filtration rate (in units) was determined as the ratio of the duration of filtration of a fixed volume of a test sample (with a certain amount of addition of a hydrocolloid) to the duration of filtration of the same volume of a control sample (without an additive). Filtration was performed using a laboratory filtration unit under identical conditions.

3. Results

At the first stage of work, beer wort with a gravity of 12 °P was used as a matrix for studying the effect of hydrocolloids on foaming processes.

As expected, the foam retention of all studied samples obtained with the addition of hydrocolloids was higher than the control (**Fig. 1**). For all samples of hydrocolloids, except for guar gum, with an increase in their dosage in the range from 0.4 to 4 g/hl of wort, an increase in this foam indicator was observed. When guar gum is used, the maximum foam stability is characteristic of the sample with the minimum dosage of the additive 0.4 g/hl, and with a further increase in the hydrocoloid content, the duration of the foam falling off decreases (**Fig. 1, *d***).

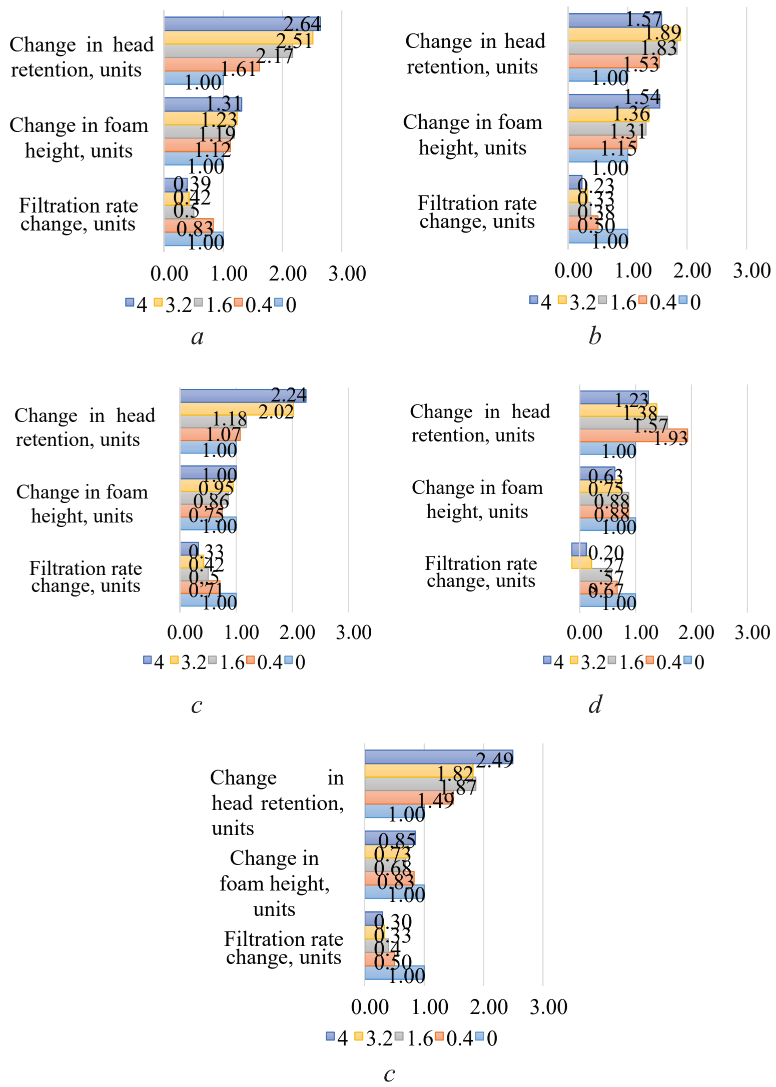

Fig. 1. Influence of the dosage of hydrocolloids (g/hl) on the foam parameters and the rate of beer filtration: *a* – highly methoxylated pectin; *b* – carboxymethyl cellulose; *c* – xanthan gum; *d* – guar gum; *e* – mixture of xanthan and guar gum

This effect of hydrocolloids on foam stability can be explained by an increase in the viscosity of the prototypes, which thereby reduces the outflow of liquid from the foam and improves its stability over a longer period of time. The correlation between head retention and beer viscosity was also confirmed in works [15, 23].

4. Discussion

In addition to head retention, an important indicator of beer foam is the appearance, structure and height of the foam. When using additives of strong thickeners (xanthan and guar gum, their mixtures), a persistent foam was formed, but dense and compact, with insufficient height – the foam height of all prototypes with these additives was less than the control. In addition, a significant increase in the viscosity of the matrix under the influence of these hydrocolloids led to a significant decrease in the filtration rate; therefore, they were not used in further studies.

Subsequently, the effect of the addition of pectin and carboxymethyl cellulose on the foaming processes was compared. Due to its anionic nature, carboxymethyl cellulose is able to interact with proteins and stabilize them [24]. As a result of its addition, simultaneously with the improvement of head retention, an increase in the height of the foam also occurs. However, the significant effect of this additive on the viscosity of the matrix, which leads to a significant decrease in the filtration rate, does not allow to recommend its stabilization of the beer foam in the technology of high gravity brewing.

The advantages of using MM pectin for this purpose have been established. Its addition allows for a significant improvement in head retention, an increase in foam height and a satisfactory filtration rate that is still less controllable. Pectin has a slight tendency to an increase in viscosity – it is characterized by a low thickening effect (**Table 1**). The expediency of stabilizing beer foam with pectin was also confirmed by the authors of works [15, 16].

The positive effect of foam stabilization with the participation of pectin can be explained as a result of the adsorption of its molecules on the verge of gas-liquid phase separation and a simultaneous increase in the viscosity of the dispersion medium [24]. In contrast to the initial hypothesis about the role of viscosity in foaming processes, it was found that the chemical structure of hydrocolloids affects the foam stability to a greater extent than the foam viscosity [23]. Taking this into account, it would be expedient to further study the effect of hydrocolloids with similar functional and technological properties, in particular, gum arabic.

The effect of foam stabilization was confirmed on samples of beer obtained by the technology of high gravity brewing. It has been established that the recommended dosage of MM pectin additive is 0.4–1 g/hl.

Thus, in order to increase the stability of the beer foam, in particular in the conditions of high gravity brewing, the addition of MM pectin is a good alternative to the use of PGA, since, among other things, the cost of pectin is 2–3 times less [18]. It should be noted the important role of pectin in the technology of functional food products as a valuable biologically active ingredient.

In further studies, the influence of the recommended additive on the colloidal stability of beer during storage is required, since important indicators of the quality of the finished beverage ultimately depend on the physicochemical equilibrium of the dispersed system – transparency and color, as well as taste and flavor.

5. Conclusions

The influence of hydrocolloids (methoxylated pectin, sodium salt of carboxymethyl cellulose, xanthan gum, guar gum, a mixture of xanthan and guar gum) on beer foam performance and its filtration rate has been studied. The use of each of the investigated hydrocolloids can significantly improve the foam stability of beer, however, it leads to a different degree of decrease in the rate of its filtration. The positive effect of increasing the height of beer foam has been found only for two additives – methoxylated pectin and sodium carboxymethyl cellulose. The advantages of pectin as an additive allowing to stabilize beer foam, in particular, in high gravity brewing, have been established. The recommended dosage of the additive is 0.4–1 g/hl. Highly methoxylated pectin is a good alternative to the currently widespread use of propylene glycol alginate.

References

[1] Kosiv, R., Kharandiuk, T., Polyuzhyn, L., Palianytsia, L., Berezovska, N. (2017). Effect of high gravity wort fermentation parameters on beer flavor profile. Chemistry & Chemical Technology, 11 (3), 308–313. doi: http://doi.org/10.23939/chcht11.03.308

[2] Yang, D., Wang, Y. (2021). Framework for a Comparative Study of Flavor Metabolites and Sensory Profiles of Six Craft Beers and Ten Large-Scale Industrial Beers in the Chinese Market. Journal of the American Society of Brewing Chemists, 1–9. doi: http://doi.org/10.1080/03610470.2021.1980677

[3] Puligundla, P., Smogrovicova, D., Mok, C., Obulam, V. S. R. (2020). Recent developments in high gravity beer-brewing. Innovative Food Science & Emerging Technologies, 64. doi: http://doi.org/10.1016/j.ifset.2020.102399

[4] Kinčl, T., Dostálek, P., Brányik, T., Olšovská, J. (2021). High-gravity brewing without adjuncts – The effect on beer parameters. LWT, 148. doi: http://doi.org/10.1016/j.lwt.2021.111755

[5] Kosiv, R., Kharandiuk, T., Polyuzhyn, L., Palianytsia, L., Berezovska, N. (2016). Optimization of Main Fermentation of High-Gravity Wort. Chemistry & Chemical Technology, 10 (3), 349–353. doi: http://doi.org/10.23939/chcht10.03.349

[6] Lenske, D., Mossel, B., Dykes, G. A. (2004). High gravity brewing and beer foam stability. Food Australia, 56 (5), 199–201.

[7] Ivanova, E. G., Kiseleva, L. V., Lenets, N. G. (2008). Penostoikost piva pri ispolzovanii stabilizatora peny Fermkap S. Pivo i napitki, 4, 24–26.

[8] Kapp, G. R., Bamforth, C. W. (2002). The foaming properties of proteins isolated from barley. Journal of the Science of Food and Agriculture, 82 (11), 1276–1281. doi: http://doi.org/10.1002/jsfa.1177

[9] Siebert, K. J. (2014). Recent Discoveries in Beer Foam. Journal of the American Society of Brewing Chemists, 72 (2), 79–87. doi: http://doi.org/10.1094/asbcj-2014-0319-01

[10] Evans, D. E., Surrel, A., Sheehy, M., Stewart, D. C., Robinson, L. H. (2008). Comparison of Foam Quality and the Influence of Hop α-Acids and Proteins Using Five Foam Analysis Methods. Journal of the American Society of Brewing Chemists, 66 (1), 1–10. doi: http://doi.org/10.1094/asbcj-2007-1129-01

[11] Evans, D. E., Sheehan, M. C., Stewart, D. C. (1999). The Impact of Malt Derived Proteins on Beer Foam Quality. Part II: The Influence of Malt Foam-positive Proteins and Non-starch Polysaccharides on Beer Foam Quality. Journal of the Institute of Brewing, 105 (3), 171–178. doi: http://doi.org/10.1002/j.2050-0416.1999.tb00016.x

[12] Kordialik-Bogacka, E., Antczak, N. (2011). Prediction of beer foam stability from malt components. Czech Journal of Food Sciences, 29 (3), 243–249. doi: http://doi.org/10.17221/225/2010-cjfs

[13] Meledina, T. V. (2003). Syre i vospomogatilnye materialy v pivovarenie. Saint Petersburg: Professiia, 304.

[14] Kosin, P., Branyik, T., Savel, J., Ulmann, F., Vlcek, J. (2018). Use of Sorbents to Increase Beer Foam Stability. Journal of the American Society of Brewing Chemists, 76 (1), 58–61. doi: http://doi.org/10.1080/03610470.2017.1398565

[15] Flavio, L. S., Sebastian, A., Tamayo, R., Aline, D. C. de B. (2020). Hydrocolloids as beers foam stabilizer. African Journal of Food Science, 14 (5), 143–153. doi: http://doi.org/10.5897/ajfs2020.1922

[16] Vjubben, M. A., Dodder A. (2000). Pat. No. RU 2159798 C2. Method of beer brewing, beer, beer foam stabilizer and method of pectins extraction from hops. MPK C12C 5/02(2006.01), C12C 7/00(2006.01), C12C 12/00(2006.01), C12H 1/14(2006.01). No. 97103511/13. declareted: 03.08.1995; published: 27.11.2000.

[17] Wüstenberg, T. (2014). Cellulose and Cellulose Derivatives in the Food Industry: Fundamentals and Applications. Wiley. doi: http://doi.org/10.1002/9783527682935

[18] Seisun, D., Zalesny, N. (2021). Strides in food texture and hydrocolloids. Food Hydrocolloids, 117. doi: http://doi.org/10.1016/j.foodhyd.2020.106575

[19] Šavel, J., Brož, A. (2006). Measurement of beer foaming power. Kvasny Prumysl, 52 (10), 314–318. doi: http://doi.org/10.18832/kp2006026

[20] Kosin, P., Savel, J., Evans, D. E., Broz, A. (2010). Relationship between Matrix Foaming Potential, Beer Composition, and Foam Stability. Journal of the American Society of Brewing Chemists, 68 (1), 63–69. doi: http://doi.org/10.1094/asbcj-2010-0114-01

[21] Kupetz, M., Rott, M., Kleinlein, K., Gastl, M., Becker, T. (2018). A new approach to assessing the crossflow membrane filtration of beer at laboratory scale. Journal of the Institute of Brewing, 124 (4), 450–456. doi: http://doi.org/10.1002/jib.529

[22] Zhuzhikov, V. A. (1980). Filtrovanie: teoriia i praktika razdeleniia suspenzii. Moscow: Khimiia, 400.

[23] Evan Evans, D., Sheehan, M. C. (2018). Don't be fobbed off: The substance of beer foam – A review. Journal of the American Society of Brewing Chemists, 60 (2), 47–57. doi: http://doi.org/10.1094/asbcj-60-0047

[24] Stephen, A. M., Philips, G. O., Williams, P. A. (Eds.) (2006). Food Polysaccharides and Their Applications. Taylor & Francis Group, 712.