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Fractional composition of beer wort with different proportions of unmalted barley in the mash and their influence on processes during mashing

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Abstract

Background: The background of this research lies in the pivotal role of protein breakdown during the mashing process for producing high-quality beer. Abnormal protein degradation can adversely impact beer properties and stability. This study explores the effects of different heat treatment temperatures on unmalted barley, aiming to enhance our understanding of how such treatments influence the fractional nitrogen composition of beer wort, thus contributing to improved brewing practices and product quality.

Methods: The methodology includes complex research steps, including malt preparation, mash production, and a thorough analysis of nitrogen fractions, which allows for a detailed study of the dynamics of proteolysis during beer mashing.

Results: In the obtained results, evaluating the amine nitrogen content in wort through chemical analysis unveils a consistent amine nitrogen level when thermal treatment of unmalted mash occurs between 100-138°C. Beyond this range, as the processing temperature of unmalted mash increases, there is a subsequent decrease in amine nitrogen content. Despite the efficient hydrolytic cleavage of starch in unmalted raw material due to elevated temperature treatment, the nitrogen content of the beer wort remains largely unaffected.

Conclusion: The authors conclude that increasing the heat treatment temperature of unmalted barley has a significant impact on the total soluble nitrogen content in the resulting beer wort. This increase is mainly attributed to the high-molecular-weight nitrogenous substances of fraction A, showcasing the potential for controlled proteolysis. Furthermore, the study suggests that achieving optimal proteolysis by employing malt with high proteolytic activity and conducting proteolysis of unmalted barley proteins prior to heat treatment enhances the overall brewing process.

Introduction

In modern brewing science, the pursuit of high-quality beer production has undergone major changes over the past decades [1]. This transformation has been spurred by an amalgamation of scientific advancements, technological innovations, and a heightened appreciation for the intricate interaction of factors that contribute to the final brew [2]. No longer confined to conventional methodologies, the contemporary brewing landscape thrives on a dynamic synergy between tradition and cutting-edge research.

The evolution is underscored by an intensified exploration of every stage in the brewing process, including raw material selection, fermentation kinetics, and post-fermentation treatments [3]. This holistic approach recognizes that the road to producing exceptional beer extends far beyond the initial recipe formulation. As brewing science delves deeper into the nuances of ingredient interaction, enzymatic reactions, and microbial behavior, it opens avenues for fine-tuning not only taste and aroma but also texture and stability [4].

Against the backdrop of this desire to develop quality brewing, the mashing process becomes an important subject of scientific research. The intricate interplay between starch conversion and protein degradation has gained prominence as a critical determinant of beer's characteristics [5]. Deviations from the established pathways of protein degradation hold the potential to wield a significant impact, altering the sensory attributes and overall stability of the end product [6]. Furthermore, the resulting enzymatic byproducts from this intricate process play a vital role in nourishing yeast during fermentation, underscoring their indispensable role in the brewing development.

Achieving a precise breakdown of proteins within raw materials during the mashing process holds equal significance in producing wort of desired quality, alongside the digestion of starches. Deviations from the norm in protein degradation can culminate in a pronounced decline in beer's sensory attributes and overall stability. Additionally, the products emerging from protein breakdown serve as essential nourishment for the sustenance of yeast during fermentation.

The products of protein breakdown – albuminoses, peptones, polypeptides, and amino acids – constitute the group of so-called "persistent soluble proteins", which, unlike true proteins, are not isolated from solution. The yeast's nourishment relies on low-molecular protein degradation byproducts, while medium-molecular components dictate the beer's richness and foam characteristics. Simultaneously, high-molecular entities contribute to foam retention [7]. Yet, an excess of these higher-molecular elements can lead to beer turbidity. Therefore, attaining superior beer quality necessitates a precise equilibrium among high, medium, and low-molecular nitrogen compounds within the wort.

The objective of this study is to investigate how the pre-treatment of unmalted barley influences the fractional nitrogen composition of the resulting wort. The study aims to shed light on the impact of different heat treatment temperatures applied to unmalted barley on the composition of the beer wort, particularly focusing on soluble nitrogen content and proteolysis dynamics during the mashing process.

Methods

Research type

A laboratory-experimental study was conducted to understand the effect of unmalted barley heat treatment on the total amount of soluble nitrogen and its components in beer wort. Detailed analysis of nitrogen fractions, proteolysis during mashing, and correlation and regression analysis were performed to obtain accurate conclusions.

Materials

The materials for the study were samples of beer mash using unmalted barley in the amount of 20, 30, and 40% of the total amount of mashing grain products [8]. Mash with unmalted barley was prepared according to the conventional method with double decoction. In all wort samples, we determined total Kjeldahl nitrogen, Lundin fraction nitrogen, and amine nitrogen using the method of estimating copper amino acid compounds. Experiments were carried out with production malt: its moisture content was 8.1%, extract and protein content per dry matter – 79.3 and 12.3%, respectively, duration of saccharification – 10 minutes, proteolytic activity – 5.3 units/100 g.

Stages of the study

- Heat treatment of unmalted barley: Unmalted barley was exposed to different temperatures ranging from 100 to 143°C. Each batch was prepared using different proportions of unmalted barley to malt – 20, 30, and 40%.
- Mashing: After heat treatment, unmalted barley was mixed with malt to make the mash. This mash was then subjected to the mashing process to produce wort.
- Analysis of wort: The resulting wort was analyzed for total soluble nitrogen and its various fractions (A, B, C). The content of amine nitrogen was determined using chemical methods.
- Comparison and analysis: The amount of soluble nitrogenous substances transferred to wort from unmalted barley after heat treatment at different temperatures was compared with the total content of

soluble nitrogenous substances formed in the wort during mashing.

- Correlation and regression analysis: The mash nitrogen data were subjected to correlation and regression analysis to reveal the relationship between the heat treatment temperature of unmalted barley and the total nitrogen content in the mash.

Data analysis

Data analysis was applied to compare the amounts of soluble nitrogenous substances transferred from unmalted barley and those formed during mashing. The content of amine nitrogen was calculated as a percentage of the total nitrogen content. The shares of different nitrogen fractions were also calculated as a percentage of the total nitrogen content. Correlation and regression analysis was performed using statistical software to identify relationships between the variables.

Results

An increase in the heat treatment temperature of unmalted barley is accompanied by a rise in the content of total soluble nitrogen (table 1).

Forms of nitrogen, mg/100 cm^3	Amount of nitrogenous substances, mg/100 cm^3, under unmalted barley heat treatment temperature, °C						
	100	110	120	127	133	138	143
Total	36.5	37.9	39.9	40.8	42.7	44.8	46.9
Lundin'sfraction: A	17.2	18.0	19.8	20.3	21.7	23.4	24.9
B	3.6	4.0	4.3	4.6	5.0	5.4	6.0
C	15.7	15.9	15.9	15.9	16.0	16.0	16.0
Amine	3.4	3.4	3.4	3.3	3.3	3.2	3.0

Source: combined by authors

Table 1: Changes in the fractional composition of nitrogenous substances in unmalted barley during heat treatment

As delineated in the figure, a notable increase of 28.5% is observed in the transition of nitrogenous compounds into soluble form at 143°C compared to 100°C. This pronounced augmentation in total soluble nitrogen content is primarily attributed to fraction A – comprising high-molecular-weight nitrogenous substances – a phenomenon closely linked to the peptization of proteins. Interestingly, the levels of amine nitrogen within fraction C, representing low-molecular-weight nitrogenous compounds, remain relatively constant during the heat treatment of unmalted barley at or above 100°C. This consistent observation suggests that the process of hydrolytic breakdown, wherein protein molecules transform into lower-molecular-weight forms, does not manifest during the course of heat treatment [9-11]. Quantitative changes in the soluble fractions of nitrogen substances in wort samples depending on the temperature of heat treatment of unmalted barley with different proportions of it in the mash are presented in Table 2. The obtained data show that when a part of malt is replaced by unmalted barley in an amount up to 40% of the mash weight, increasing the temperature of its heat treatment up to 100°C and higher leads to an increase in the content of total soluble nitrogen in the mash, which gets higher the greater the share of unmalted barley in the mash [12, 13]. The increase in the content of total soluble nitrogen occurs evenly due to all fractions. It is noticeable, however, that the more unmalted barley there is in the mash, the more the rise in total soluble nitrogen occurs due to high-molecular-weight nitrogenous substances of fraction A.

Content of unmalted barley in the mash, %	Processing temperature of unmalted barley, °C	Totalnitrogen, mg/100 cm^3	Aminenitrogen, mg/100 cm^3	Lundin's fraction nitrogen, mg/100 cm^3		
				A	B	C
20	100	76.3	18.2	15.7	10.5	50.1
	110	76.7	18.2	15.7	10.6	50.4
	120	77.0	18.3	15.9	10.6	50.5
	127	78.0	18.2	16.2	10.9	50.9
	133	79.1	18.3	16.4	11.0	51.7
	138	80.0	18.2	16.5	11.1	52.4
	143	80.5	18.0	16.7	11.6	52.2
30	100	74.9	16.8	16.3	10.0	48.6
	110	75.6	16.9	16.5	10.1	49.0
	120	75.6	16.8	16.6	10.0	49.1
	127	76.0	16.8	16.7	9.7	49.6
	133	77.7	16.7	16.9	10.5	50.3
	138	79.0	16.9	17.2	11.2	50.6
	143	79.0	16.7	17.4	10.9	50.7
40	100	59.5	15.4	13.8	7.8	37.9
	110	60.2	15.5	14.0	7.9	38.3
	120	60.9	15.5	14.3	7.8	38.8
	127	62.3	15.7	14.7	8.1	39.5
	133	63.7	15.6	14.9	8.4	40.4
	138	65.1	15.2	15.1	8.8	41.2
	143	66.5	14.7	15.4	9.2	41.9

Source: combined by authors

Table 2: Effect of unmalted barley processing temperature on the fractional nitrogen composition of wort at different proportions of unmalted barley in the mash.

Content of unmalted barley in the mash, %	Processing temperature of unmalted barley, °C	Totalnitrogen,mg/100 cm³	Aminenitrogen, % tototal	Lundin's fraction nitrogen, % to total		
				A	B	C
20	100	76.3	23.80	20.60	13.76	65.64
	110	76.7	23.80	20.52	13.78	65.70
	120	77.0	23.70	20.65	13.78	65.57
	127	78.0	23.40	20.73	13.96	65.31
	133	79.1	23.20	20.69	13.91	65.40
	138	80.0	22.80	20.63	13.84	65.53
	143	80.5	22.30	20.80	14.31	64.89
30	100	74.9	22.40	21.75	13.37	64.88
	110	75.6	22.40	21.83	13.38	64.79
	120	75.6	22.20	21.96	13.07	64.97
	127	76.0	22.10	21.97	12.71	65.32
	133	77.7	21.50	21.76	13.53	64.71
	138	79.0	21.40	21.80	14.08	64.12
	143	79.0	21.20	22.00	13.82	64.18
40	100	59.5	25.80	23.28	12.96	63.76
	110	60.2	25.70	23.26	13.10	63.64
	120	60.9	25.50	23.56	12.63	63.81
	127	62.3	25.20	23.67	12.92	63.41
	133	63.7	24.40	23.36	13.14	63.50
	138	65.1	23.30	23.2	13.53	63.26
	143	66.5	22.10	23.10	13.78	63.12

Source: combined by authors

Table 3: Ratio of soluble fractions of nitrogen in mash depending on processing temperature of unmalted barley and its share in the mash.

Processing temperature of unmalted barley,°C	Content of unmalted barley in the mash, %								
	20			30			40		
	Totalnitrogenin the wort, mg/100 cm³	Transferred with unmown barley, mg/100 cm³	Gained from malt and enzymes,mg/100 cm³	Totalnitrogenin wort,mg/100 cm³	Transferred with unmown barley,mg/100 cm³	Gained from malt and enzymes,mg/100 cm³	Totalnitrogenin wort,mg/100 cm³	Transferred with unmown barley,mg/100 cm³	Gained from malt and enzymes,mg/100 cm³
100	76.3	7.3	69.0	74.9	10.9	64.0	59.5	14.6	44.9
110	76.7	7.6	69.1	75.6	11.4	64.2	60.2	15.2	45.0
120	77.0	8.0	69.0	75.6	12.0	63.6	60.9	16.0	44.9
127	78.0	8.2	69.8	76.0	12.4	63.8	60.9	16.0	44.0
133	79.1	8.5	69.8	77.7	12.8	64.9	63.7	17.1	46.6
138	80.0	9.0	71.0	79.0	13.4	65.6	65.1	17.9	47.2
143	80.5	9.4	71.1	79.0	14.1	64.9	66.5	18.8	47.7

Source: combined by authors

Table 4: Effect of the processing temperature of unmalted barley on proteolysis during mashing.

At 20 and 30% of unmalted barley in the mash, the increase is 5.5%, and at 40%, the increase is 13.4%. The content of amine nitrogen in the wort with the processing temperature of unmalted barley rising from 100 to 138°C remains unchanged. It is only with a further increase in the temperature that amine nitrogen content slightly lowers, which is associated with the intensification of the melanoidin-formation reaction [14].

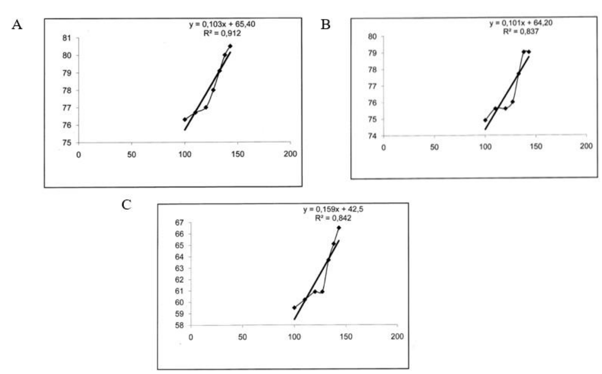
To produce high-quality beer it is necessary to achieve a certain ratio of high, medium, and low-molecular nitrogen compounds in the wort.

For this reason, we examined the change in the content of soluble nitrogen fractions in the wort concerning the total soluble nitrogen at different processing temperatures of unmalted barley (Table 3).

In order to elucidate the influence of unmalted barley's heat treatment temperature on the process of proteolysis, a comparative analysis was undertaken. This involved juxtaposing the quantity of soluble nitrogenous substances that migrate into the wort from the heat-treated unmatured barley at varying temperatures with the overall content of soluble nitrogenous compounds engendered within the wort during the mashing process (Table 4).

The acquired data reveals that elevating the heat treatment temperature of unmalted barley beyond 100°C marginally intensifies the interaction between malt enzymes and unmalted barley proteins [15].

Based on the results of studies on the nitrogen composition of wort, we conducted a correlation and regression analysis (Figure 1).



Source: combined by authors

Figure 1: Correlation and regression relationship between the processing temperature of unmalted barley and total nitrogen content in wort with the content of unmalted barley inmash equal to 20% (A), 30% (B), and 40% (C).

Discussion

The analysis reveals a strong direct correlation between the processing temperature of unmalted barley and the total nitrogen contained in the mash [16, 17].

The rise in total soluble nitrogen content occurs uniformly at the expense of all fractions. However, it is apparent that the more unmalted barley there is in the mash, the more the increase in total soluble nitrogen occurs at the expense of high-molecular-weight nitrogenous substances of fraction A. This consistency reinforces the idea that temperature plays a important role in the proteolysis process [18], enabling the release of valuable compounds into the wort.

Several studies [19, 20] have explored the impact of heat pre-treatment on unmalted barley and its subsequent effects on beer production. One notable similarity with these prior studies is the consensus regarding the effectiveness of elevated temperatures for achieving enhanced hydrolysis of unmalted starch [21, 22]. These studies, similar to the current one, have reported that heat treatment at higher temperatures is more effective in breaking down starch in unmalted barley compared to boiling at atmospheric pressure [23-26].

In terms of the effect on nitrogen composition, the current study's findings align with prior research suggesting that the breakdown of proteins during the mashing process is critical for achieving desired beer properties [27, 28].

The research draws the following conclusions: Initially, the chemical assessment of amine nitrogen content in the mash, contingent on the heat treatment temperature of unmalted barley, demonstrates that maintaining heat treatment within 100-138°C sustains consistent amine nitrogen content. However, as the processing temperature of unmalted mash exceeds this range, amine nitrogen content diminishes. This trend holds true as the proportion of unmalted barley in the mash increases.

Furthermore, subjecting unmalted barley to high-temperature heat treatment, instrumental for starch hydrolysis, does not significantly modify the nitrogen composition of the resultant beer wort. In the preparation of mash featuring unmalted barley, prioritizing malt with heightened proteolytic activity and robust dissolution capability takes precedence. Ensuring proteolysis of unmalted barley proteins at the preliminary stages, prior to heat treatment of the unmalted portion of the mash, emerges as a more crucial factor for attaining desired outcomes compared to temperature-related adjustments during heat treatment.

Future research could be studying the potential synergistic effects of combining different heat treatment methods with varying proportions of unmalted barley in the mash. This could involve investigating how techniques such as enzymatic treatments, different mashing regimes, or even sequential heat treatments could further enhance the breakdown of proteins and the resulting wort composition.

Author Contributions

The authors collectively conducted and designed the research, performed experiments, analyzed data, and synthesized findings, contributing equally to advancing our understanding of unmalted barley's impact on wort composition and its implications for the brewing industry.

Conflict of Interest

The authors declare that there is no conflict of interest.

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