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ORIGINAL RESEARCH PAPER

RESEARCH ON THE USE OF THE AHP METHOD IN THE SENSORY ANALYSIS OF BUCKWHEAT AND SORGHUM BEER

Adriana Dabija[1*], Marius E. Ciocan[1], Ancuța Chetrariu[1], Dadiana Dabija[2]

[1]Faculty of Food Engineering, Stefan cel Mare University of Suceava, 720229 Suceava, Romania
[2]Faculty of Economics, Administration and Business, Stefan cel Mare University of Suceava, 720229 Suceava, Romania

*Corresponding author: adriana.dabija@fia.usv.ro

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Abstract: In the sensory analysis of the food and beverage industry, the use of advanced decision-making procedures like the Analytical Hierarchy Process (AHP) is yet largely unexplored. Analytical Hierarchy Process (AHP) is a decision-making tool that reflects human thinking, breaking down complex decisions into one-to-one comparisons. The AHP method enhances sensory analysis precision by reducing expert variability and allowing quick removal and retraining of tasters who deviate significantly from the group. Consumer demand for diverse beverages has led to exploring alternative raw materials in beer production, with buckwheat and sorghum being notable due to their nutritional and gluten-free qualities. The paper explores how AHP, a decision-making tool, can enhance sensory analysis for buckwheat and sorghum beers through pair wise comparisons, revealing subtle sensory profiles.

Keywords: *Analytical Hierarchy Process (AHP), consumer decision making, gluten-free beer*

INTRODUCTION

Exploration of new ingredients and brewing methods has increased in the brewing sector, which is known for its long history and constant quest of innovation. When it comes to the brewing industry, where creativity and skill meet, sensory analysis is critical [1, 2]. Sensory evaluation is a widely used method in the food industry to evaluate beer samples and estimate overall acceptability. It consists of analytical and affective measurements, with analytical tests detecting differences and descriptive analysis describing the product. Affective analysis determines which samples are preferred over others. Descriptive sensory evaluation provides a detailed profile of a product, correlated with instrumental tests for product development and quality improvement [3 – 5].

Beer producers need to adapt their offerings to meet the changing tastes of consumers, who are looking for more distinctive and varied flavor profiles. In this industry, sensory analysis goes beyond the conventional domains of flavor and aroma to include aspects like mouthfeel, appearance, and even the sound of a beer being opened. Gaining an understanding of the complexities of sensory perception enables brewers to improve brewing processes, fine-tune recipes, and ultimately create drinks that appeal to today's discriminating palate [6 – 8].

Precise sensory analysis is more important than ever as brewers strive to satisfy a wide and discriminating customer base. The foundation of flavor profiling and quality assurance in brewing has long been established by traditional sensory evaluation techniques [9]. Classical sensory analysis in brewing is usually conveyed as a professional assessment of beer characteristics such as flavor, aroma, appearance, and mouthfeel and conducted by a trained panel. This traditional method has played a significant role in influencing brewing procedures and preserving the authenticity of well-known beer varieties [10]. Sensory evaluation is a method for obtaining comprehensive information about food products, but it has several drawbacks. It requires extensive training for food is time-consuming and expensive and may result in imprecise data due to inter- and intra-expert variability [11]. Statistical methods used in sensory analysis are also ineffective due to imprecision. Additionally, sensory analysis does not measure the impact of quality attributes on product acceptance or rejection, and this prevents us from knowing which attributes consumers' value most when evaluating a product [12]. Finally, sensory evaluation has been characterized as imprecise and with uncertain repeatability. Furthermore, the limitations of conventional sensory analysis may not fully provide insightful observations about the complex interactions between the sensory elements that shape the whole customer experience, in a context where the brewing industry has seen a rise in experimenting with unusual ingredients and brewing techniques [13, 14].

Contemporary consumer demands for diverse and innovative beverages have led to the exploration of alternative raw material in beer production. Among these, buckwheat and sorghum are particularly noteworthy due to their distinct nutritional profiles and gluten-free qualities, which make them desirable choices for customers with dietary requirements [5]. These raw materials offer a gluten-free alternative and a chance to develop distinctive flavors derived from particular terroirs because they are hardy in a variety of climates. The final product's sensory qualities are greatly influenced by the raw materials used in the brewing process, which introduces subtleties do not present in conventional beers made from barley. It's critical to comprehend the subtle differences in these alternative beers' flavors as both brewers and drinkers search for new experiences. The goal of this research is to provide useful information to the scientific community and the brewing industry by illuminating the unique sensory characteristics of buckwheat and sorghum beers and demonstrating how the Analytical Hierarchy Process (AHP) method can be used in practice to improve our comprehension of these complex flavor profiles.

Analytical Hierarchy Process (AHP), developed in the 1970s by Dr. Thomas Saaty and Dr. Ernest Forman, is a decision making and management tool that reflects human thinking. AHP not only aids in decision-making but also offers a coherent justification for the optimal choice by breaking down complex decisions into a series of one-to-one comparisons and synthesizing the outcomes [14]. The methodology was later expanded to handle complex interactions, optimize resource allocations, and incorporate collaborative brainstorming and consensus opinion features. Recent advancements include structural capabilities, algorithms, and simulation to identify and measure risks and opportunities with uncertainty. Fogliatto *et al*., 1999, were the first to propose AHP and sensory analysis in product development and improvement [15]. Later, Fogliatto & Albin, 2003, proposed the indirect pairwise comparison (IPC) method for sensory data collection and analysis [16]. Gurmeric *et al*., 2013, compared different samples according to sensory scores, performing different multicriteria decision techniques (AHP, SAW, ELECTRE and TOPSIS) [17]. The multicriteria AHP technique is also an alternative when selecting the sensory vocabulary to characterize and explain consumer preferences against the ISO 11035 standard [13]. However, the application of sophisticated decision-making tools, such as the Analytical Hierarchy Process (AHP), in the sensory analysis of food and beverage industry remains relatively unexplored.

This technique structures the decision model in the form of a hierarchy with criteria and alternatives. The goal of the decision-making process (selection of the best beer sample) is decomposed into a predefined number of criteria (the sensory properties of the beer samples). It relies on the judgment of experts (trained members) who must use pairwise comparisons between items. Participants are asked to make two types of pairwise comparisons: (a) a pairwise comparison of alternatives (beer samples) in terms of attributes; and (b) a pairwise comparison between attributes. Each time, the expert must indicate which of the two compared elements is preferred according to a 9-point scale. From the answers given and following the mathematical principles of the method, an individual prioritization is obtained for each of the elements of the hierarchy [13, 18].

In this research, the aim is to study whether AHP can complement the sensory analysis of gluten-free beer performed by a trained panel to minimize the disadvantages defined above and to better meet consumer expectations regarding beer quality. In particular, the AHP method will be applied to find out the weight of attributes involved in consumer judgment when evaluating the quality of gluten-free beer. This paper aims to determine how AHP, a decision-making instrument extensively used in many other domains, can improve the accuracy and comprehensiveness of sensory analysis for beers obtained in the pilot beer station from buckwheat and sorghum whose technological process we have detailed in our previous research [5]. Through pair wise comparisons, the AHP method systematically evaluates and prioritizes sensory attributes, thus providing an organized way to discover the subtleties that characterize these alternative beers' sensory profiles.

MATERIALS AND METHODS

The beer was obtained in a Brewferm (Belgium) microbrewery equipment. The recipes studied are presented in Table 1 and the technological process we have detailed in our previous research [5].

Table 1. *Variants of manufacturing recipes studied* [5]

Ingredient	Brewing recipe variant			
	CS	**B1**	**B2**	**B3**
Barley malt, [%]	100	-	-	-
Unmalted buckwheat, [%]	0	100	0	50
Unmalted sorghum, [%]	0	0	100	50
Termamyl classic enzyme preparation, [%]	-	1	1	1
Initial *p*H of the mash	6.30	6.39	6.68	6.60

The beer samples were tasted by a group of 18 experts (henceforth panelists or tasters) who were previously trained, with a total of 4 samples per tasting: control sample (CS), B1 (buckwheat), B2 (sorghum), B3 (buckwheat and sorghum) and a repetition as a panel check system in each of the tasting sessions. The panel consisted of 9 men and 9 women. The two tasting sessions took place on two different days. Each sample was presented to the panel members, coded with two letters and in random order. Sensory properties (investigated criteria) were selected based on the standard of beer sensory analysis. The experts were asked to rate the following sensory properties using the 9-point intensity scale mentioned above: appearance, color, smell, taste, CO_2 impregnation (carbonatation) and foam persistence.

Each of the group members was given a questionnaire to perform the pair wise comparisons required by the AHP. Two sets of comparisons were made, those between tasting attributes and those between beer samples. Since the attributes appearing in the AHP models were the ones they usually use in their organoleptic evaluation sheet, it was not necessary to explain to them the meaning of the variables to be evaluated. However, it was necessary to introduce them to the concept of AHP and its associated comparisons so that they understood the format of the questionnaire that was handed to them. The process of explaining the questionnaire took about 30 minutes, after which all experts could complete it. This process took about another 30 minutes. An example excerpt from this first AHP questionnaire is shown in Table 2.

Each criterion is evaluated separately. For example, to evaluate the quality of a beer, in the first line of the table the taster chooses whether the taste of the beer is much more important than its appearance. Questionnaires were completed by each individual taster and collected on the same day. Once responses were collected from all participants, they were processed using Superdecisions© v. 2.4.0 software (Creative Foundations, Pittsburgh, USA). Superdecisions© v. 2.4.0 software is a decision-making tool that helps decision-makers structure decisions into parts, allowing for comparisons and risk controls. It helps people deal with intuitive, rational, and irrational aspects, as well as risk and uncertainty in complex situations. The software is user-friendly, intuitive, and structured, making it valuable for researchers, novices, and category experts. It allows users to drill down to their level of expertise and apply judgment to objectives important to achieving goals. The results of the weights of all variables were analyzed both individually and as a group. The method was used in a doctoral thesis to optimize gluten-free beer manufacturing.

Table 2. *Example of questions received by each taster for evaluation of sensory properties*

From your point of view, which attribute is more important and to what extent to evaluate the QUALITY of a beer?										
	EX	MF	F	MO	=	MO	F	MF	EX	
C1 Taste	9	7	5	3	1	3	5	7	9	**C2** Aspect
C1 Taste	9	7	5	3	1	3	5	7	9	**C3** Color
C1 Taste	9	7	5	3	1	3	5	7	9	**C4** Smell
C1 Taste	9	7	5	3	1	3	5	7	9	**C5** Carbonatation
C1 Taste	9	7	5	3	1	3	5	7	9	**C6** Foam stability
C2 Aspect	9	7	5	3	1	3	5	7	9	**C3** Color
C2 Aspect	9	7	5	3	1	3	5	7	9	**C4** Smell
C2 Aspect	9	7	5	3	1	3	5	7	9	**C5** Carbonatation
C2 Aspect	9	7	5	3	1	3	5	7	9	**C6** Foam stability
C3 Color	9	7	5	3	1	3	5	7	9	**C4** Smell
C3 Color	9	7	5	3	1	3	5	7	9	**C5** Carbonatation
C3 Color	9	7	5	3	1	3	5	7	9	**C6** Foam stability
C4 Smell	9	7	5	3	1	3	5	7	9	**C5** Carbonatation
C4 Smell	9	7	5	3	1	3	5	7	9	**C6** Foam stability
C5 Carbonatation	9	7	5	3	1	3	5	7	9	**C6** Foam stability

RESULTS AND DISCUSSION

The group results obtained for the attributes were calculated using the geometric mean of the individual expert judgments as recommended by Saaty & Peniwati, 2008 [19]. Moreover, before proceeding to the aggregation of the judgments, the judgments made by each of the experts were checked for coherence. After analyzing the individual judgments, it was concluded that two of the experts were too inconsistent (consistency ratio > 0.20). Therefore, the final analysis was performed for the 16-member group.
The group results are presented in Tables 3 and 4, where the percentages of importance of each sensory property are represented. The most valued sensory property was taste (60.3 %), followed by appearance (18.7 %), color (10.3 %), while carbonatation, smell and foam are the least prioritized attributes.

Table 3. *Priorities: Resulting weights for criteria based on pairwise comparison*

Attribute (Criteria)		Priority	Scale	(+)	(-)
1	Taste	60.3 %	1	47.5 %	47.5 %
2	Aspect	18.7 %	2	9.2 %	9.2 %
3	Color	10.3 %	3	4.5 %	4.5 %
4	Carbonatation	4.4 %	4	1.6 %	1.6 %
5	Smell	3.4 %	5	1.8 %	1.8 %
6	Foam stability	2.9 %	6	1.6 %	1.6 %

The number of comparisons = 15; The consistency ratio (CR) = 12 %

Table 4. *Decision Matrix: The weighting of the results is based on the principal eigenvector of the decision matrix*

	1	2	3	4	5	6
1	1	9.00	8.00	9.00	9.00	9.00
2	0.11	1	3.00	8.00	6.00	5.00
3	0.12	0.33	1	3.00	6.00	4.00
4	0.11	0.12	0.33	1	2.00	2.00
5	0.11	0.17	0.17	0.50	1	2.00
6	0.11	0.20	0.25	0.50	0.50	1

Principal eigenvalue = 6.571
Eigenvector solution: 6 iterations, delta = 9.4E-8

From the analysis of the results presented in Figure 1 it can be observed that the highest score was presented by option B3 (beer obtained from 50 % buckwheat flour and 50 % sorghum flour), placing this sample in the top of tasters' preferences, closely followed by the control sample. The other two variants, 100 % buckwheat beer (B1) and 100 % sorghum beer (B2) were ranked much lower in the preferences of the panel experts.

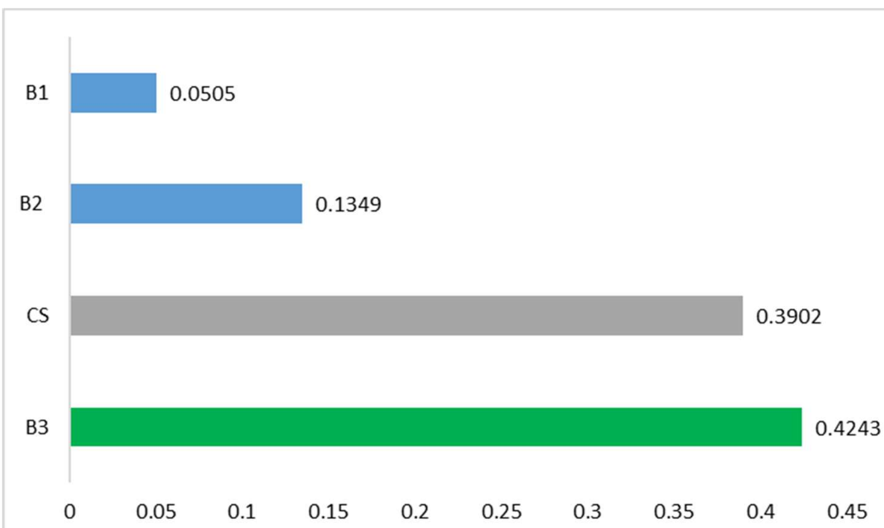

Figure 1. *Classification of beer samples following sensory analysis using the AHP method*

Figure 2 highlights the weight of the importance of each sensory criterion in the total score awarded. It is observed that the most important for the experts from the sensory criteria taken in the study was taste (60.30 %), followed by aspect (18.70 %) and color (10.30 %), the least important being foam stability (2.90 %). While taste, aspect and color are obviously the main characteristics that influence the consumer's decision on which beer they prefer, the results show that carbonation, smell, and foam stability are of lesser importance and will not influence the choice of the preferred gluten-free beer [5].

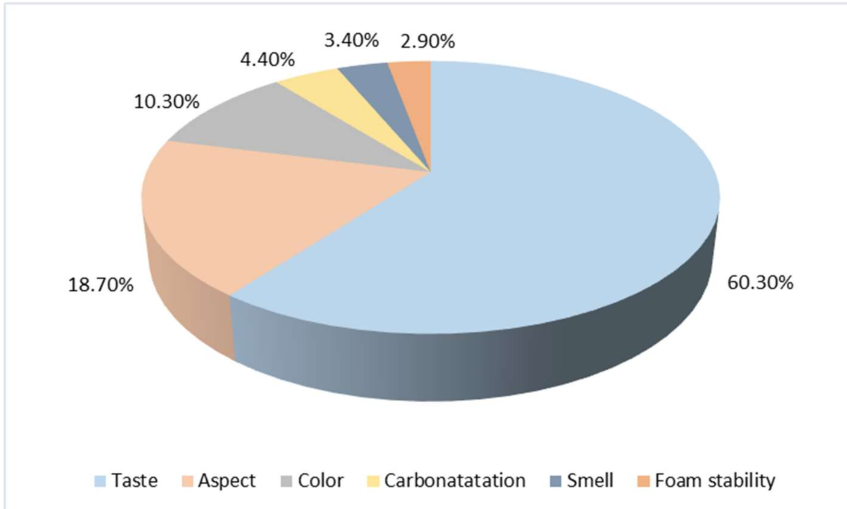

Figure 2. *The importance of the criteria in ranking the beer samples taken in the study*

Figure 3 summarizes the individual results of the sensory analysis for all the beer samples taken in the study. Each column in Figure 3 shows the proportion of each criteria within the structure, that were the basis behind the decision to rank the beer samples by the experts. The highest score was obtained by B3 (beer obtained from 50 % buckwheat flour and 50 % sorghum flour), followed by CS (beer obtained from 100 % barley malt), while B1 (beer obtained from 100 % buckwheat flour) obtained the lowest score for all sensory criteria analyzed. This ranking of beer samples confirms the results obtained through the standard sensory analysis method used in a similar experiment on gluten free beers by Ciocan *et al*. (2023) [5].

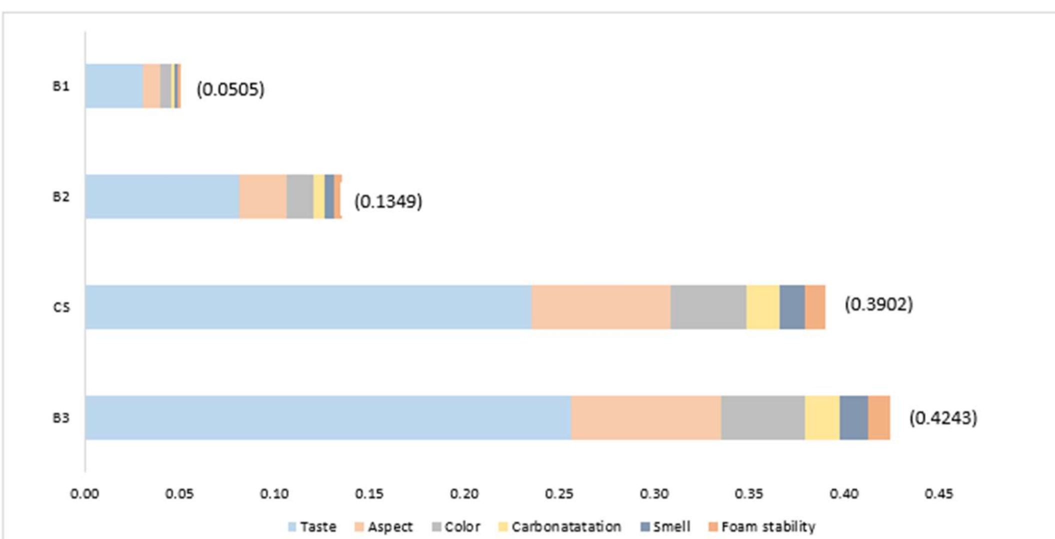

Figure 3. *The ranking of the analyzed alternatives and the structure of the criteria behind the decision to rank the beer samples taken by the tasters*

The tasting profile of the panelists

It is also interesting to establish the individual profile of each panelist. Thus, the most relevant attributes for each panelist can be determined, and we can even see if there are tasters with similar or very different profiles [12]. In Figure 4 (where the Y-axis is the percentage of importance of each attribute), one can see the intervariability present between tasters, an interesting result that shows how each panelist performs their own tasting, which could not have been obtained by the standard method of beer sensory analysis.

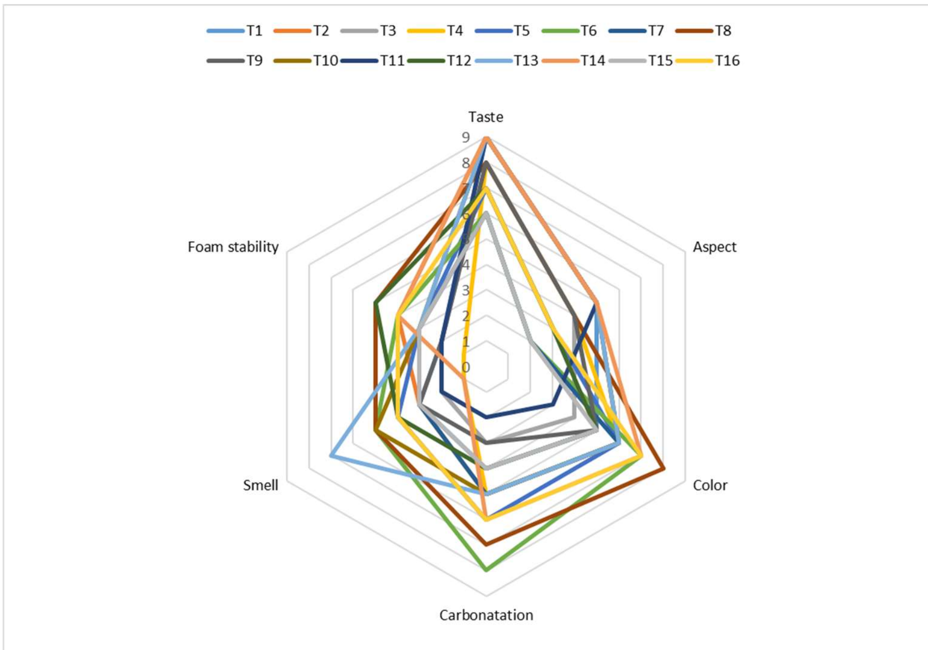

Figure 4. *Comparisons of individual AHP profiles of participating beer tasters*

CONCLUSION

Sensory analysis helps determine the acceptability of food products by consumers. Although widely used, there are a number of drawbacks and attempts have been made to reduce them by combining existing sensory analysis methods with AHP. One drawback is the need for long-term training of panel members and experts. Using the standard method, tasters rate the beer according to the scoring scale. This makes training the tasters long and expensive until they are able to rate the various attributes on a scale of 0 to 5 (SR 13355-1/June 1997). In contrast, the AHP method compares two different sensory properties, row by row, using a relative scale. This paired comparison is much easier than benchmarking and therefore requires less training. In this sense, it could be very useful for consumer panels that are not trained as experts. Moreover, it has the advantage that tasters do not need to be specially trained for each type of beer. This allows companies or laboratories to switch from one product to another more quickly, without the need for specific preparation for each beer. As a result, applying the AHP method reduces the costs and time needed to prepare the sensory panels.

General AHP analyzes tend to consider only positive priority for criteria (the higher the value of a criterion, the higher the user's satisfaction). However, someone choosing an assortment of beer considers both the pleasantness (pleasure) and dislike (displeasure) aspects of the beer in their decision process. Since the pleasure-displeasure relationship does not form an inverse relationship, i.e. a lack of pleasure does not necessarily represent displeasure, it cannot be measured as positive priority with an inverse relationship. For this reason, it is better to also consider the negative priority in some of the attributes (the lower the value of a criterion, the higher the user's satisfaction).

In conclusion, AHP is shown to complement standardized sensory analysis, overcoming many of the disadvantages of this type of procedure. First, it saves time and money in training panel members and conducting the evaluation process. Second, it increases the accuracy of the results. Third, it more quickly detects panel members who need to be sent for retraining. Finally, thanks to the collected information, the methodology of physico-chemical characterization of food products can be improved. In the case of gluten-free beer, where alternative options are high due to the competitiveness of the industry, saving time and costs can help the food industry respond better and faster to consumer expectations. This is why the results are of interest to brewers and marketing researchers.

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