Agriculture and Food

AIMS Agriculture and Food, 10(2): 461–485.
DOI: 10.3934/agrfood.2025023
Received: 30 January 2025
Revised: 31 May 2025
Accepted: 13 June 2025
Published: 02 July 2025

https://www.aimspress.com/journal/agriculture

Research article

Cultural Heritage on gastronomic usages of honey: Recipe analysis and cluster segmentation

Sofia G. Florença[1], Ana C. Ferrão[1], Cristina A. Costa[1], Maria João Barroca[2], Aida Silva[2], Soraia I. Pedro[3], Ofélia Anjos[3] and Raquel P. F. Guiné[1,*]

[1] CERNAS-IPV Research Centre, Polytechnic University of Viseu, Campus Politécnico, Viseu, Portugal
[2] Agrarian School, Polytechnic University of Coimbra, Coimbra, Portugal
[3] CERNAS-IPCB Research Centre, Polytechnic University of Castelo Branco, Portugal

* **Correspondence:** Email: raquelguine@esav.ipv.pt; Tel: +351232446600.

Abstract: Honey has been a food product used by humans since immemorial times, both for nutritional and medicinal reasons. Gastronomic recipes contain a great deal of knowledge and cultural heritage, both in the form of traditional ancient recipes as well as innovative and modern recipes. This study intends to investigate the use of honey in gastronomy with the purpose of increasing knowledge regarding the culinary usages of honey, much valued by traditional culture as well as modern practices. An analysis was conducted based on 150 recipes that include honey as an ingredient. A classification of the recipes according to several types of recipes and cooking variables was made, and ingredients were categorised according to the defined classes. Results show that honey is added to recipes essentially as a secondary ingredient in most dishes, while for desserts, it has a more prominent role. Factor analysis revealed two factors: one linked with cooking variables and the other associated with ingredients. Cluster analysis showed five clusters, distinguished according to dish type and ingredient groups, among other distinctive variables. In conclusion, this work showed that honey is a very versatile ingredient with broad applicability in gastronomic preparations.

Keywords: honey; culinary; gastronomic preparation; ingredients; cultural heritage

1. Introduction

Humans have consumed natural products since antiquity, also to cure or prevent a variety of

diseases and conditions. Historically, honey bees have been used since the Stone Age [1]. The honey bee has been known to man for almost 40,000 years, according to a careful analysis of stone writing left by primitive peoples. Some religious scriptures like the Talmud, the Bible, and other sacred books of Persia, China, Egypt, and India mention honey as a health-giving food [2]. Honey and beeswax have always attracted man's attention, being connected to the evolution of humanity [3]. Honey is traditionally used for both nutritional and medicinal purposes in most ancient cultures. Since antiquity, it has been used to cure or prevent various diseases and complications, namely obesity and diabetes, being known for its antioxidant, antibacterial, hypolipidemic, and hypotensive activities [4–6].

Honey is a sweet fluid produced by *Apis mellifera* L. (the honey bee) from honeydew and floral nectar, which is collected from flowers and stored inside the hive within wax-form structures named honeycombs [3,7]. Honey is an energy-dense food product, providing nutritive components besides other health-enhancing properties. Honey contains more than 180 chemicals, most of which are carbohydrates, such as fructose and glucose, of which fructose is present in higher concentrations. Additionally, honey also contains enzymes, vitamins, amino acids, proteins, and polyphenols [8–11]. Honey's bioactive compounds, which include flavonoids (e.g., quercetin, luteolin, apigenin, kaempferol, chrysin, galangin), phenolic acids, antioxidant enzymes (e.g., catalase, CAT, and glucose oxidase), carotenoids, and ascorbic acid, contribute to its potent antioxidant capacity and anti-inflammatory response [12–14]. Honey constitutes one of the best-known therapeutic foods. Although its pharmacologic applicability dates back many centuries, recent research has confirmed its health effects by revealing the existence of a number of compounds with desirable health effects such as antioxidant, anti-inflammatory, anti-diabetic, or anticancer effects, among others [15]. For this reason, in the 20th century, honey was recognised as a promising health food [4], and research on this "miraculous" food continues [16,17]. Apitherapy, a field of alternative medicine that uses bees, honey, and other bee products to treat a variety of diseases, has developed in recent decades [18]. However, there are some rare health risks associated with honey that must not be ignored, such as the possible presence of natural plant toxins [19], veterinary antibiotics [20], or toxic metals like nickel that present possible carcinogenic risks [21].

Gastronomy is a distinctive field of science that enables us to better understand indigenous/traditional varieties of food and cuisines, as well as modern food preparations created by the most prominent chefs around the world. The term *gastronomy* is defined and conceptualised from different perspectives and encompasses several academic disciplines. With the advancement in this field, diverging concepts evolve from gastronomy; nowadays, food is increasingly perceived as an art, an expression of culture, part of a heritage identity, and even a passion. Culinary practices are different according to geography and culture [22]. Breaking through the science behind every food product, food scientists and gastronomy chefs have explored various kinds of ingredients used for food preparations, from those more traditional to those most innovative [23–28]. UNESCO's List of Intangible Cultural Heritage accounts for a high number of recognitions in the field of gastronomy, making it possible to preserve the identities of those foods while also disseminating them at the international level, emphasising the values that cuisine, its usages, and customs carry to the society and to the culture of a population, allowing the conservation of the natural and cultural heritage of a territory [29,30].

Honey is a pleasant, viscous liquid with a delectable taste, with very versatile applicability in the food domain, and a colour ranging from quite transparent to amber or black, depending on the flowers visited by the bees. It is consumed alone or accompanied by other foods, either in the natural state or

in culinary preparations, which can include thermal cooking [31]. Honey can be used in the confection of different recipes; undoubtedly, its most relevant usage is in sweets and pastries due to its sweetening potential [32–35]. However, it is also used in other foods, such as meat, and as an antioxidant agent [36–38]. Honey is still used to produce alcoholic and non-alcoholic drinks. Mead is a traditional alcoholic beverage obtained by fermenting honey with the action of appropriate yeasts [39,40].

There is a trend for sharing recipes online, increasing the building of knowledge and the possibility of using data mining strategies and tools to retrieve, investigate, and analyse the data of gastronomic recipes as a way to build new knowledge fields [41]. Additionally, it contributes to the preservation of food and cultural heritage. The objective of this work was to provide an overview of the utilisation of honey as an ingredient in food preparations. For this, an analysis of recipes was conducted based on some parameters related to the dish type and confection method, including cooking time, type of ingredient, and the moment of incorporation into the culinary preparation.

2. Materials and methods

For this work, a collection of 150 random recipes that include honey was selected from printed culinary books or from online cooking websites. Different types of recipes were included in the analysis, considering the diversity of honey's use. The selection of the recipes was based on some criteria, namely, a search of different sources. On the one hand, traditional cookbooks are a recognised form of recipe dissemination because they tend to cover a wide variety of domains, from traditional recipe collections to modern recipes proposed by recognised chefs. On the other hand, recipes were also collected from the internet, as it allowed us to obtain recipes from different sites, covering a variety of traditions and types of utilisation, and therefore, a wider range of possibilities. All recipes analysed were written in Portuguese (search words were in Portuguese); therefore, when conducting our internet search, recipes written in Portuguese were included, regardless of being from Portugal, Brazil, Mozambique, Angola, etc..., basically covering the countries where the Portuguese is an official language (nine in total). On the other hand, the physical recipe books analysed included those gathered by the team members, i.e., those available among the team members and their households; all were in Portuguese.

A previous screening of the recipes was made to confirm their usefulness for the present study, namely, the presence of honey in different roles. This was because our intention was not to only include recipes of sweet dishes, where honey would be used just for its sweet nature. In fact, the aim was to obtain recipes that came from different sources, including the more traditional as well as the more innovative. Also, recipes covered a wide diversity of dishes, from meat to fish, apart from sweets or desserts. Once recipes were obtained following these selection objectives, they were classified based on different criteria, namely dish type, whether it included cooking or not, the cooking method utilised, cooking time, the moment of incorporation of the honey, and its role in the recipe. The classification criteria were:

- Dish type: soups or starters; breakfast or tea snacks; main dishes (differentiating by fish, meat, vegetarian, or other main dishes, e.g., shellfish); dessert; bakery products or cookies; other types of dish (e.g., toppings, sauces).
- Cooking: whether the recipe involved cooking or not;
- Cooking method: boiling; roasting; grilling; baking; frying; or other cooking methods;
- Cooking time: short (up to 10 minutes); medium (between 10 and 30 minutes); long (over 30 minutes);

- Moment of incorporation of the honey: beginning, middle, end;
- Role of the honey: primary or secondary ingredient.

For each recipe, these classification criteria were applied, and all ingredients were registered in a Microsoft Excel database used for the analysis. Also, an SPSS database was created for the statistical analysis of the results. As previously mentioned, the data collection was initially done in Portuguese; only during data analysis were recipes translated into English for the preparation of the manuscript.

The classification of the ingredients was based on two different criteria: by food groups (cereals, dairy and eggs, fish, fruits, herbs, meat, nuts and dried fruits, oils and drinks, sauces, shellfish, spices, vegetables and legumes, others) and by relevance of the ingredients in the recipe (major ingredients, complementary ingredients, minor ingredients).

Descriptive statistics and statistical tests were used for the treatment of the data, like the Chi-squared test complemented with the Cramer's V coefficient [42,43]. The Cramer's V coefficient means that an association is nonexistent for values close to zero and strong for values higher than 0.5 [44].

Further statistical analyses were made, namely factor analysis (FA) and cluster analysis (CA), as described by Florença et al. [42]. These types of statistical analyses were made with the objective of finding patterns that allow grouping of the recipes according to some common features. Measures of KMO and Bartlett's test were applied as well, and loading values in each factor under 0.4 were excluded [45,46]. The CA was applied to the factors previously obtained, following the procedure described by Florença et al. [42]. The software used was SPSS version 28 (IBM Corp., USA), and a significance of 5% was considered.

The Sankey diagram was obtained online using the software SankeyMATIC (SankeyMATIC: Build a Sankey Diagram). To build the word clouds, the online tool WordCloud Generator, MonkeyLearn (https://monkeylearn.com/word-cloud/) was used.

3. Results and discussion

3.1. Analysis of the recipes

Table 1 shows the classification of the recipes according to the criteria defined, i.e., dish type, cooking, cooking method, cooking time, moment of incorporation of honey, and role of honey in the recipe.

Although all dish types are represented, as shown in Table 1, some categories stand out with a higher number of recipes, namely main dishes with meat, as well as bakery and pastry products (n = 21 in both cases). There is a lower number of recipes for other dishes (n = 8) and vegetarian dishes (n = 14). Figure 1 shows, as examples, two recipes that include honey: a recipe for a main dish consisting of fish (salmon) with honey sauce and a recipe for some cookies including honey.

According to the Second Global Report on Gastronomy Tourism [47], the concept of tourism includes cultural practices as well as local history and values being recognised as part of the cultural heritage that contributes to the encouragement of local and regional economies. The gastronomic component of tourism has emerged remarkably in recent years, assuming a unique role in the promotion of tourist destinations and promoting local economies while offering unique local products to visitors [48]. Local products based on indigenous ingredients are highly valued in this context, and their utilisation for gastronomy is a valuable way to meet the past and the future of culinary preparations [25,49–51]. In the present day, consumers are pivotal to the acceptance of food products in general, and honey in particular [52].

Table 1. Classification of the recipes with honey analysed in this study.

Criteria	Sub-criteria	N	%
Dish type (N = 150)	Soup/Starter	19	12.7
	Breakfast/tea snack	15	10.0
	Fish main course	17	11.3
	Meat main course	21	14.0
	Vegetarian main course	14	9.3
	Other types of main courses (shellfish, pizzas, …)	19	12.7
	Dessert	16	10.7
	Bakery/pastry	21	14.0
	Others (not accounted for previously)	8	5.3
Cooking (N = 150)	Yes	123	82.0
	No	27	18.0
Cooking method	Boiling	3	2.4
(N = 123)	Roasting	30	24.4
	Baking	11	8.9
	Grilling	25	20.3
	Frying	7	5.7
	Others	47	38.2
Cooking time	Short time (up to 10 min)	40	32.5
(N = 123)	Medium time (from 10 to 30 min)	49	39.8
	Long time (over 30 min)	34	27.6
Moment of	Beginning	84	56.0
incorporation of honey	Middle	38	25.3
(N = 150)	End	28	18.7
Role of honey in the	Primary ingredient	56	37.3
recipe (N = 150)	Secondary ingredient	94	62.7

Figure 1. Culinary preparation of a recipe with salmon and honey (left) and homemade honey cookies (right).

Honey is reported as nature's gift to humankind. It is described as a "superfood" with distinctive qualities and delicious flavour, bearing health advantages [53]. By many, honey is considered a "wonder food" that, besides its appreciated taste, also presents a number of health advantages. Scientific evidence has demonstrated that honey contains bioactive substances that have beneficial effects on humans, such as antioxidant capabilities or antimicrobial properties, either isolated or in combination with other food ingredients. Among its bioactive compounds, phenolic and enzymatic components have been reported as the main ones responsible for the health effects of honey [16,17,53–55]. However, the most prominent use of honey has been as a food and as an ingredient in a high number of food preparations [56]. Records of baking with honey exist in ancient Egypt dating from 1200 B.C. [57].

Honey can be used in recipes as a main ingredient, being added in high concentration in the recipe, or as a secondary ingredient, typically in smaller amounts and with roles that complement the main flavour. The use of honey in sweet preparations and desserts typically comprises its use as a major ingredient, for example, in bakery products where honey is introduced into cookies, cakes, or desserts, like honey mousse [58]. The natural sweetness of honey, provided by the sugars naturally present in high concentration, makes it an excellent ingredient to incorporate into sweet preparations. Given that honey is rich in natural sugars, including fructose, glucose, and sucrose, there is no need to incorporate other added sugars into the recipe [59]. Also, honey has been incorporated into the development of novel food products as a natural sweetener and for possessing additional health benefits. As an example, Patrignani et al. [34] described the development of a honey-based biscuit filling aimed at industrial production and commercialisation. Another work by Arii and Nishizawa [60] described the development of a new sweet food made from honey. However, the use of honey goes beyond its role as the primary ingredient; it is also used in many gastronomic preparations of dishes that are not considered sweet, such as meat or fish dishes. When honey is used in these types of dishes, the quantities added to the recipes tend to be smaller, and its role is, for example, to produce a sour-sweet taste or a sweet-acidic taste that is often valued as exotic by consumers. Gastronomic representations of consumers vary according to many factors, like socio-cultural factors [61–63] or personal issues [64,65].

Most of the recipes in Table 1 involve cooking (82%), and the methods most frequently used are roasting (24.4%), grilling (20.3%), and baking (8.9%). With regards to cooking time, 40 recipes have a cooking time of up to 10 minutes, 49 recipes have a cooking time between 10 and 30 minutes, and a smaller number of recipes (n = 34) have a cooking time of over 30 minutes (Table 1). In many recipes, honey is subjected to a heating procedure. When honey is subjected to high temperatures, such as boiling or oven baking, and then cooled, this must be done carefully to minimise undesirable effects of heating [66]. Exposure to high temperatures can have adverse effects on the bioactive properties of honey as well as on its quality aspects, namely regarding its colour and rheology [67–72].

Honey is a primary ingredient in more than a third of the recipes (n = 56) and has a secondary role in the remaining 94 recipes. The moment of incorporation of the honey into the recipe was also investigated, and in most recipes, honey is added at the beginning of the preparation (n = 84), being added in the middle of the process for 38 recipes, and at the end for 28 recipes (Table 1).

Figure 2 presents the Sankey chart for the 150 recipes according to the different classification criteria defined. The Sankey diagram has five levels, as follows: the role of honey, whether it involves cooking or not, the cooking method, cooking time, and the moment of incorporation of the honey. The flow analysis reveals that there is a prevalence of recipes that include honey as a secondary ingredient, and in most cases, these preparations involve a cooking procedure (81 recipes). For the recipes that do not involve cooking, 6 of them incorporate the honey in the beginning, 9 in the middle, and 12 at the

end of the preparation. Of the 30 recipes that involve roasting, the most frequently used cooking methods, only a small number have a short cooking time (4), with an equal number of recipes with medium and long cooking times (13 recipes each). The terminal nodes correspond to the moment of incorporation of the ingredients.

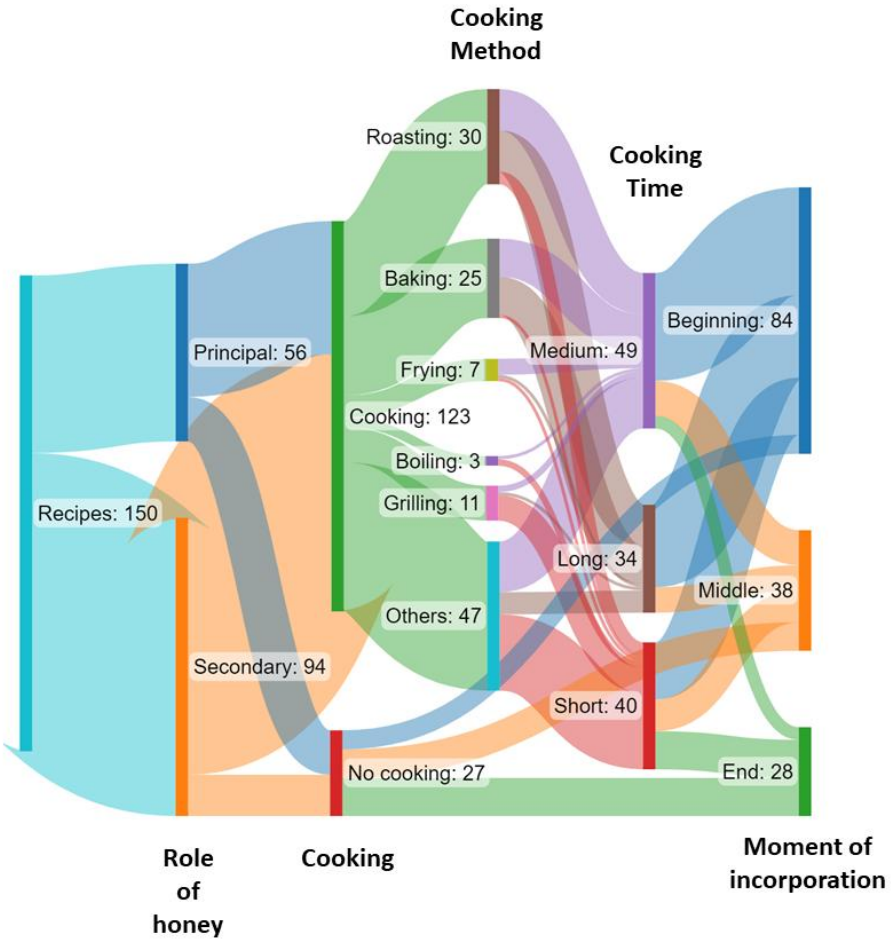

Figure 2. Sankey diagram representing the distribution flux of the recipes.

Considering that the role of honey is a pivotal variable, further analysis was made according to whether honey is a primary or a secondary ingredient. Table 2 shows the results of the chi-square test of the variables "role of honey" versus "dish type", revealing significant differences ($p < 0.001$) between the groups. These differences were identified through the values of the adjusted residuals as being located in the groups of soups and starters, desserts, and other dishes. The Cramer's V coefficient was $V = 0.444$, which is indicative of a strong association between the role of honey and the dish type.

Table 3 gathers the results of the chi-square tests for those variables connected to the preparation of the recipes (involving cooking, cooking method, cooking time, and moment of incorporation of the honey) versus the role of honey. The results reveal significant differences only for the variable "moment of incorporation of the honey" ($p = 0.020$), specifically located in the group of recipes in which the honey is added at the end of the preparation process.

Table 2. Dish type according to the role of honey in the recipe.

Dish type	Role of honey		Chi-square test			Cramer's coefficient V
	Primary ingredient (N = 56)	Secondary ingredient (N = 94)	Chi^2	df	p	
Soup/starter	5.4%	17.0%*	29.530	8	<0.001	0.444
Breakfast/tea snack	16.1%	6.4%				
Fish main course	5.4%	14.9%				
Meat main course	8.9%	17.0%				
Vegetarian main course	3.6%	12.8%				
Other types of main courses	12.5%	12.8%				
Dessert	21.4%*	4.3%				
Bakery/pastry	16.1%	12.8%				
Other dishes	10.6%*	2.0%				
Total	100.0%	100.0%				

Table 3. Preparation variables according to the role of honey in the recipe.

Preparation variables	Role of honey		Chi-square test			Cramer's coefficient V
	Primary ingredient	Secondary ingredient	Chi^2	df	p	
Cooking[1]	N = 56	N = 94	2.967	1	0.085	0.141
Yes	75.0%	86.2%				
No	25.0%	13.8%				
Cooking method[2]	N = 42	N = 81	4.723	5	0.451	0.196
Boiling	4.8%	1.2%				
Roasting	19.0%	27.2%				
Grilling	7.1%	9.9%				
Baking	28.6%	16.0%				
Frying	4.8%	6.2%				
Others	35.7%	39.5%				
Cooking time[2]	N = 42	N = 81	1.371	2	0.504	0.106
Short (≤10 min)	33.3%	32.1%				
Medium (10–30 min)	42.5%	37.0%				
Long (>30 min)	21.4%	30.9%				
Incorporation of honey[1]	N = 56	N = 94	7.823	2	0.020	0.228
Beginning	64.3%	51.1%				
Middle	28.6%	23.4%				
End	7.1%	25.5%*				

[1]Number of recipes = 150; [2]number of recipes = 129 (only those that imply cooking). *Percentages that are significantly different ($p < 0.05$) from those expected by a random distribution of values.

3.2. Ingredient analysis

Honey can have positive effects on other products, besides contributing to flavour, rheology, and health. For example, honey can help preserve foods due to the presence of antioxidant substances [73]. On the other hand, cakes made with honey remain softer for more extended periods because they tend to absorb moisture from the air [66].

The flavour of honey is determined by the species of plant used as a food source by the honey bees, as well as the physical location or terroir. This diversity will produce variable results when honey is incorporated into recipes, and chefs and mixologists explore these features in their creations [66]. In the United States, in Spicewood, in the Hill Country, Chef Taylor Hall owns a thematic restaurant, the Apis Restaurant & Apiary, which was considered one of Texas's best restaurants of 2015. In the menu, the chef explores the gastronomic possibilities of honey, which is considered the main ingredient in many of the recipes [66]. In the King Bee bar (in East Austin, Texas, USA), Billy Hankey and his team use honey combined with a local gin to produce an innovative and much-appreciated frozen drink [66]. The gastronomic applicability of honey is much valued, and that results in a high number of recipes that are varied in nature, not restricted to sweet foods, but also as a garnish and ingredient in main dishes of meat and fish. Culinary books all over the world and the internet are full of recipes that contain honey as a primary or secondary ingredient. These confirm the role of honey as a staple ingredient since antiquity, with the potential to continue playing a main role in culinary preparations.

For the 150 recipes analysed, all ingredients, besides honey, were registered and classified according to the two criteria established: 1) By food groups, including cereals, dairy and eggs, fish, fruits, herbs, meat, nuts and dried fruits, oils and drinks, sauces, shellfish, spices, vegetables and legumes, and others; and 2) by relevance of the ingredients in the recipe, namely major ingredients, complementary ingredients, and minor ingredients. These criteria were used to analyse the results.

Table 4 shows the number of ingredients according to each category.

Table 4. Number of ingredients in each category.

Classes	Groups	N	%
Major ingredients	Cereal-based ingredients	81	7.3
	Fish	18	1.6
	Meat	29	2.6
	Shellfish	16	1.4
	Vegetables and legumes	127	11.4
Complementary ingredients	Dairy and eggs	133	12.0
	Fruits	101	9.1
	Nuts and dried fruits	41	3.7
Minor ingredients	Herbs	56	5.0
	Oils and drinks	107	9.6
	Sauces	57	5.1
	Spices	198	17.8
	Other ingredients	148	13.3
	Total	1112	100.0

The number of ingredients in each recipe varied from a minimum of 2 to a maximum of 18. A

total of 1112 ingredients were registered for the 150 recipes, as shown in Table 4. The category with the highest number of ingredients was spices (n = 198), followed by dairy and eggs (n = 133).

3.2.1. Major ingredients

The ingredient groups that were considered as major ingredients were cereals, fish, meat, shellfish, and vegetables and legumes. Figure 3 shows the number of recipes that include each of the ingredients according to the groups.

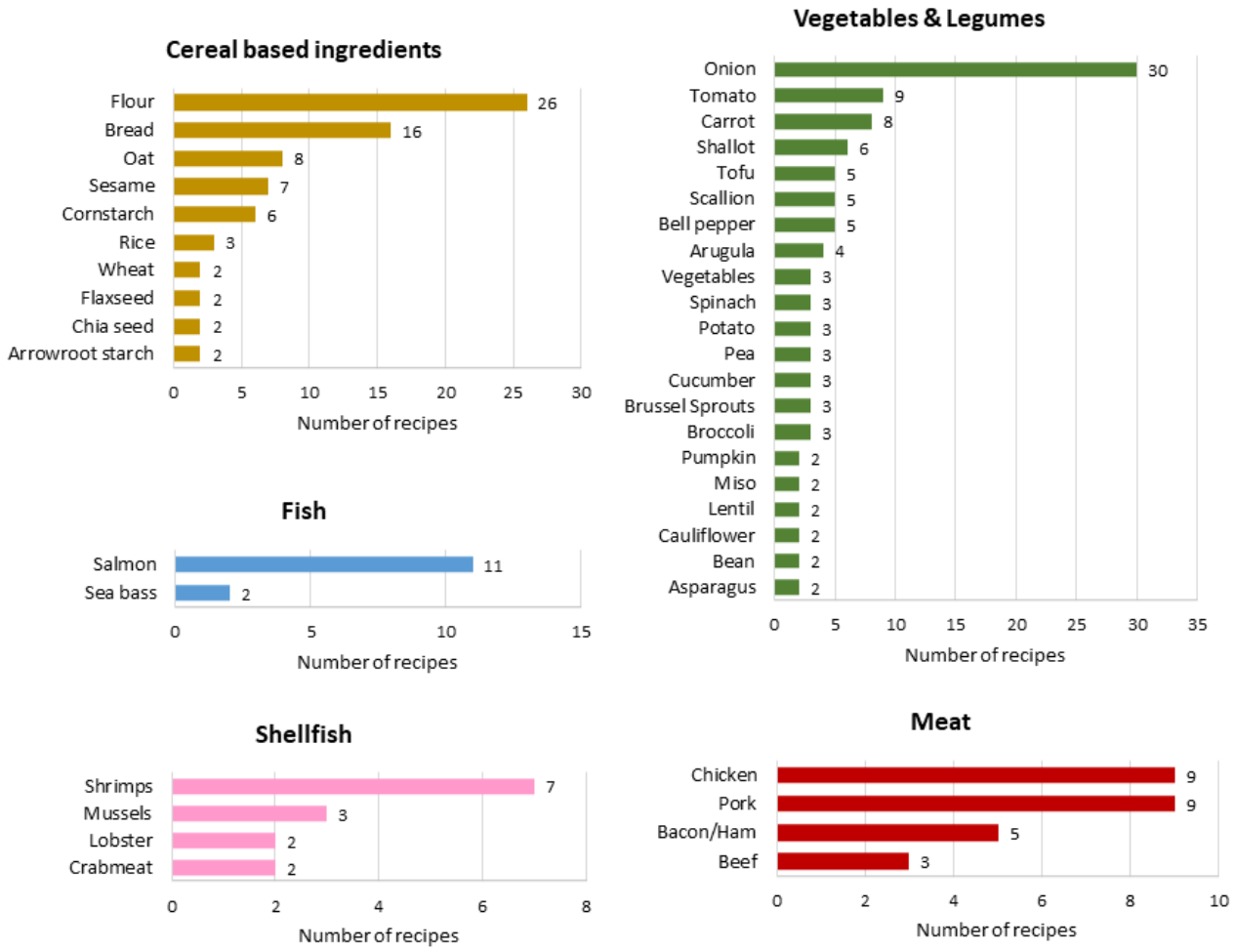

Figure 3. Recipe count of the major ingredients according to the food groups.

The count of the ingredients included those that appeared in at least two different recipes. A high number of recipes included cereal-based ingredients, dominated by flour (n = 26) and bread (n = 16), besides other cereal-based products (Figure 3). With respect to the vegetables' group, onion is present in a total of 30 recipes, and the second most relevant ingredient was tomato (n = 9). In relation to fish, only two appeared more than once, with a high prevalence of salmon (n = 11) and sea bass appearing in two recipes. However, other fish were also identified, but appeared only once; for example, dolphinfish, grouper, halibut, octopus, or red snapper. With respect to shellfish, the most used were

shrimps (n = 7), followed by mussels (n = 3), and lobster and crabmeat (n = 2 for both). In this case, there were other products that appeared in only one recipe, such as clams or scallops. With respect to meat, most recipes included chicken or pork (n = 9 in both cases), followed by meat products like ham or bacon (n = 5), and beef in three recipes. Other types of meat appearing in a single recipe were lamb, duck, and turkey.

Considering the ingredients that constitute the major ingredients class, the most relevant globally are flour, onion, and bread, as illustrated in the word cloud shown in Figure 4.

Figure 4. Word cloud of the ingredients considered major in the recipes.

3.2.2. Complementary ingredients

The ingredient groups considered complementary were dairy and eggs, fruits, and nuts and dried fruits. These were considered to complement the main ingredients and were used in the recipe in non-negligible amounts, like the major ingredients. Figure 5 presents the number of recipes that included these groups, with emphasis on the use of fruits, particularly citrus, such as lemon (n = 20), orange (n = 12), lime (n = 8), or their juices. Nuts and dried fruits are also used in some recipes, particularly almonds (n = 9) and walnuts (n = 6). Dairy products and eggs are present in a great majority of recipes, highlighting the presence of butter in 38 recipes, cheese in 27, and eggs in 25 recipes. The types of cheese used in the recipes were varied and included blue cheese, feta, brie, camembert, cream cheese, gorgonzola, goat cheese, halloumi, mozzarella, paneer, parmesan, ricotta, and Roquefort.

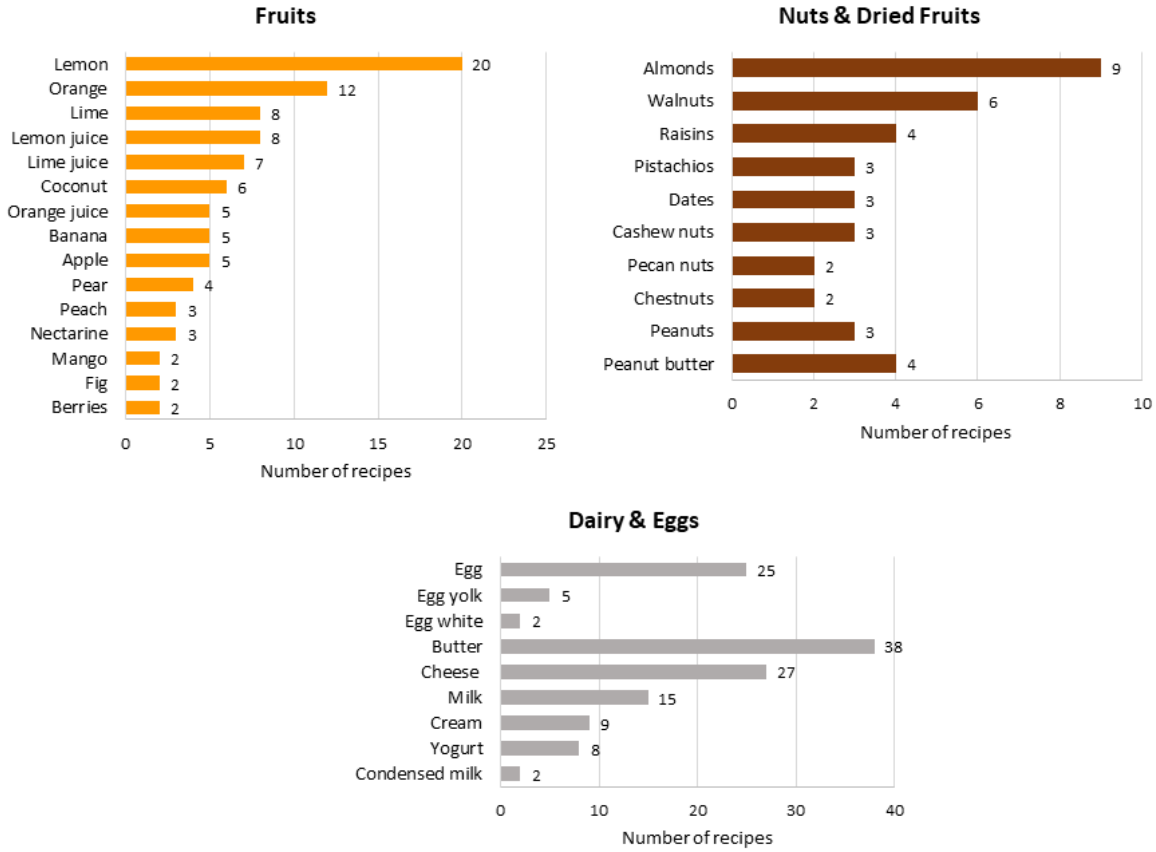

Figure 5. Recipe count of the complementary ingredients according to the food groups.

Considering the complementary ingredients globally, the word cloud in Figure 6 reveals the prevalence of butter, egg, and cheese, but also milk, lemon, and orange.

Figure 6. Word cloud of the ingredients considered complementary in the recipes.

3.2.3. Minor ingredients

The groups that were considered as minor ingredients were herbs, oils and drinks, sauces, spices, and others. These were considered minor ingredients because their utilisation was much lower than that of the major or complementary ingredients. Figure 7 shows that the most frequently used herbs were parsley (12 recipes) and coriander (10). Spices were present in many of the recipes, especially pepper (n = 54) and garlic (n = 48). Olive oil was the most used fat (n = 43), while vinegar was used in 22 recipes. A diversity in vinegar types was also observed, with the use of wine, balsamic, rice, champagne, and apple cider vinegars. The most used sauces were soy and hot sauce (n = 20 and n = 7, respectively). With respect to other ingredients not classified in the previously mentioned categories, salt and sugar stand out as the most used, in 81 and 28 recipes, respectively.

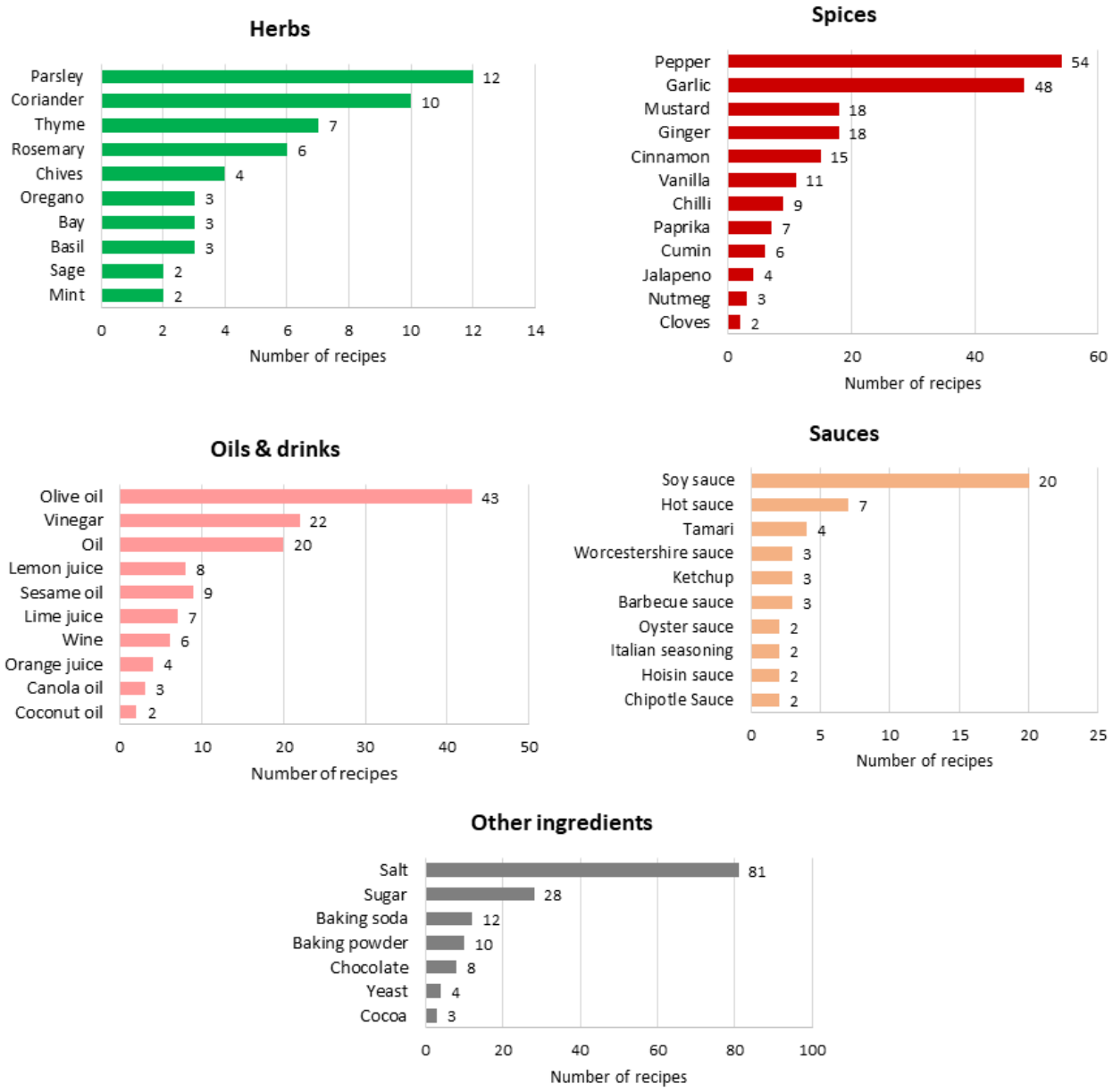

Figure 7. Recipe count of the minor ingredients according to the food groups.

Figure 8 presents the word cloud built with all ingredients from the class of minor ingredients, evidencing a wide variety of different ingredients, with a prevalence of pepper, salt, garlic, oil, olive oil, and vinegar.

Figure 8. Word cloud of the ingredients considered minor in the recipes.

3.3. Factor analysis and cluster analysis

The value of the KMO obtained was 0.598, and the Bartlett's test was significant ($p < 0.001$), confirming the suitability of the data for the application of FA, which extracted two factors: F1 explaining 29.0% of the variance, and F2 explaining 22.9% of the variance. Factor F1 included variables associated with the preparation of the recipes: dish type, cooking method, cooking time, and moment of incorporation of honey, with factor loadings of −0.458, 0.626, −0.784, and 0.721, respectively. Factor F2 accounted for variables associated with the recipes' ingredients: group and class of ingredients, with factor loadings of 0.825 and 0.815, respectively. Figure 9 shows the rotated component plot, evidencing the two factors previously described, one around the x-axis (F1) and the other in the proximity of the y-axis (F2).

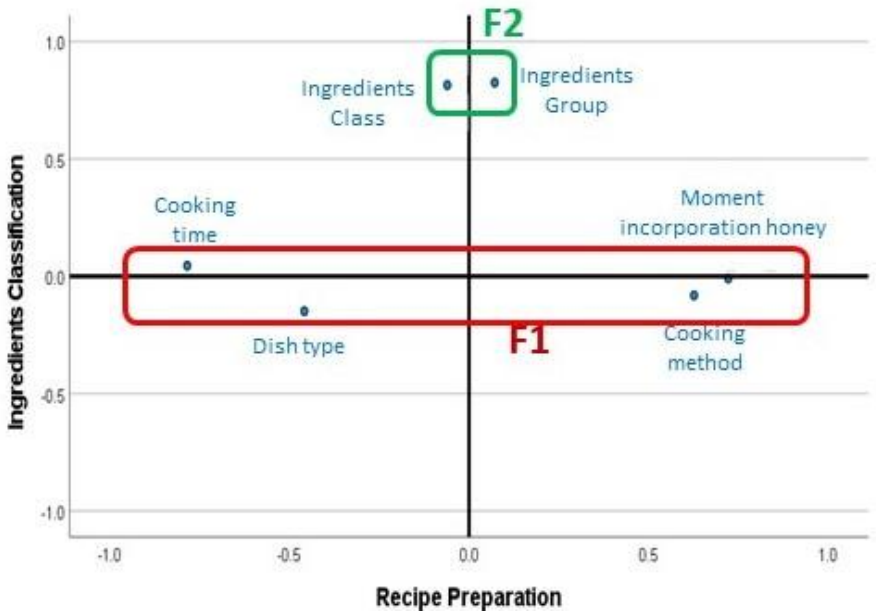

Figure 9. Component plot obtained through factor analysis, evidencing the solution obtained with Varimax rotation.

Based on the coefficients of the agglomeration schedule that were obtained with CA by the Ward hierarchical method, five clusters were established (Figure 10). This number of clusters was then used to perform CA with the K-means method, as shown in Table 5. The cases (corresponding to the ingredients) were relatively evenly distributed by the five clusters, with percentages around 20%–25%, with a minor representation in cluster 5, with only around 13% of the ingredients. Analysis of variance (ANOVA) showed a significant differentiation between the factors ($p < 0.001$), evidenced by the high values of F, which represents the ratio between the variation between groups and the variation within the groups.

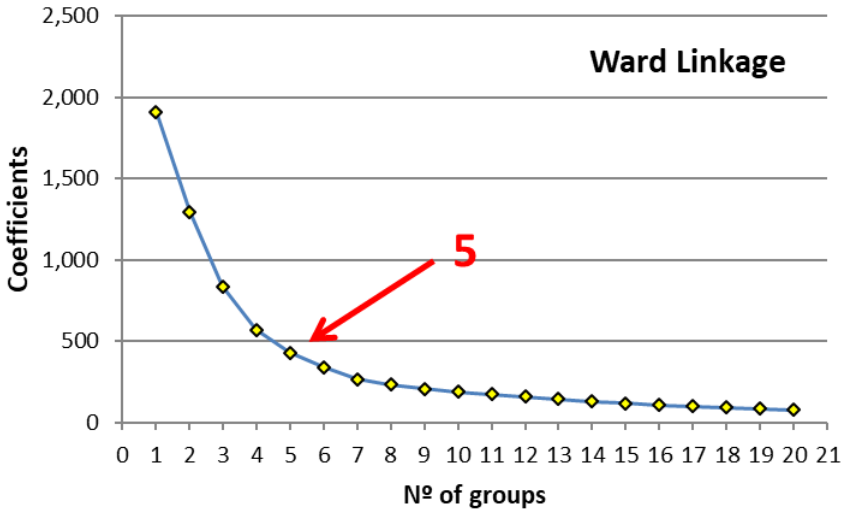

Figure 10. Coefficients of the agglomeration schedule in hierarchical cluster analysis.

Table 5. K-means cluster analysis results.

Cluster	% of cases	Cluster centres	
		F1 (recipe preparation)	F2 (ingredients classification)
C1	25.3	−0.789	−1.044
C2	19.9	−1.019	0.930
C3	22.5	0.090	0.704
C4	19.5	0.990	−0.882
C5	12.8	1.476	0.732
ANOVA (F; p-value)		1217.5; <0.001	843.9; <0.001

Once the CA was established, the characterisation of the cases (recipes) in each of the clusters can be attained through crosstabs and chi-square tests considering the variables that were used to define the clusters. Results are presented in Table 6. For all variables, the p-value was significant ($p < 0.001$), and Cramer's coefficients were high in practically all cases, particularly for the variables cooking time ($V = 0.536$), ingredients' groups ($V = 0.512$), moment of incorporation of the honey ($V = 0.493$), and cooking method ($V = 0.406$), meaning that the association between the variables was strong. There was just one exception for the variable role of honey in the recipe, for which the Cramer's coefficient was low ($V = 0.172$); in this case, the association was weak, even though it was significant.

Table 6. Association between cluster membership and the working variables.

Variables and groups	Cluster membership (% of cases)					
	C1	C2	C3	C4	C5	Total
Dish type[1]	$p < 0.001$; $V = 0.347$					
Soup/starter	0.0	0.5	12.1*	12.3*	11.5*	6.7
Breakfast/tea snack	1.7	0.0	4.2	10.2*	8.2*	4.4
Fish main course	8.3	4.7	30.2*	15.0	13.1	14.4
Meat main course	12.8	27.4*	20.0	13.9	18.9	18.3
Vegetarian main course	7.0	10.0	3.3	19.8*	31.1*	12.3
Other types of main courses	14.0	12.6	20.5	27.2*	17.2	18.2
Dessert	12.8*	8.9	4.7	1.6	0.0	6.4
Bakery/pastry	40.9*	35.4*	2.3	0.0	0.0	17.9
Other dishes	2.5	0.5	2.7	0.0	0.0	1.4
Cooking method[1]	$p < 0.001$; $V = 0.406$					
Boiling	1.7	2.6	3.3	4.2	0.0	2.5
Roasting	29.3*	47.9*	24.6	2.1	0.0	22.9
Baking	46.7*	36.4*	12.6	0.0	0.0	21.9
Grilling	7.9	6.3	17.2*	7.6	0.0	8.6
Frying	4.5	2.6	8.8*	3.7	4.9	5.0
Others	9.9	4.2	33.5	82.4*	95.1*	39.1

Continued on the next page

Variables and groups	Cluster membership (% of cases)					
	C1	C2	C3	C4	C5	Total
Cooking time[1]	$p < 0.001$; $V = 0.536$					
Short	9.5	0.5	34.9	70.1*	82.8*	34.6
Medium	43.4*	31.6	57.2*	26.7	17.2	37.6
Long	47.1*	67.9*	7.9	3.2	0.0	27.8
Honey incorporation[1]	$p < 0.001$; $V = 0.493$					
Beginning	80.6*	83.7*	64.6	32.1	9.8	59.1
Middle	19.4	16.3	32.1*	31.0*	22.1	24.3
End	0.0	0.0	3.3	36.9*	68.1*	16.6
Role of honey[1]	$p < 0.001$; $V = 0.172$					
Primary ingredient	37.2*	24.7	32.6	22.5	13.9	27.8
Secondary ingredient	62.8	75.3	67.4	77.5	86.1*	72.2
Ingredients[1]	$p < 0.001$; $V = 0.512$					
Cereal-based ingredients	15.7*	0.0	0.0	13.9*	0.0	6.7
Fish	4.5*	0.0	0.0	3.7*	0.0	1.9
Meat	6.6*	0.0	0.0	6.4*	0.0	2.9
Shellfish	2.9	0.0	0.0	4.8*	0.0	1.7
Vegetables and legumes	13.7	0.0	10.2	29.9*	2.5	11.9
Dairy and eggs	28.9*	0.0	0.0	17.7*	0.0	10.8
Fruits	19.8*	0.0	0.0	16.0*	0.0	8.2
Nuts and dried fruits	7.9*	0.0	0.9	6.5*	0.0	3.5
Herbs	0.0	10.0*	9.8*	1.1	6.6	5.2
Oils and drinks	0.0	12.6	16.3*	0.0	24.6*	9.3
Sauces	0.0	4.7	15.3*	0.0	11.5*	5.9
Spices	0.0	31.1*	30.7*	0.0	38.4*	18.0
Other Ingredients	0.0	41.6*	16.8	0.0	16.4	14.0

[1]Chi-square test p-value and Cramer's coefficient. *Percentages that are significantly different ($p < 0.05$) from those expected by a random distribution of values.

The results in Table 6 show that cluster C1 corresponds mostly to bakery and pastry products, which include mostly ingredients from the dairy and eggs group, where honey is a secondary ingredient incorporated at the beginning of the preparation; these recipes involve baking and a long or medium cooking time.

Cluster C2 includes mostly recipes of main dishes with meat and also bakery/pastry, where the cooking methods are roasting and baking, with a long cooking time, with honey as a secondary ingredient added at the beginning of the preparation, and whose ingredients are essentially categorised as others and spices.

Cluster C3 includes recipes mostly of main dishes with fish, where the cooking method is classified as other, with a medium cooking time, where honey is a secondary ingredient added in the beginning, and which includes mostly spices as ingredients.

Cluster C4 corresponds to recipes that are mostly classified as others or vegetarian, with a cooking method classified as others, with a short cooking time, where honey is a secondary ingredient added at the end of the preparation of the recipe, and which includes essentially ingredients from the

vegetables and legumes group.

Finally, cluster C5 corresponds to recipes belonging mostly to vegetarian main dishes, prepared with other cooking methods, where the cooking time is short, honey is a secondary ingredient added in the end, and which includes mostly spices.

4. Conclusions

This work revealed the multiplicity of applications of honey in gastronomic preparations of a variety of dishes besides desserts or bakery/pastries, such as soups/starters, breakfast/tea snacks, and main fish, meat, and vegetarian dishes, and others. Honey appears in the recipes essentially as a secondary ingredient, which is mostly incorporated into the recipes at the beginning of the preparation. Honey is combined with a great variety of ingredients, particularly flour, bread, onion, salmon, chicken, butter, cheese, egg, milk, lemon, pepper, garlic, oil, olive oil, sugar, and salt.

Factor analysis revealed two factors, one associated with cooking variables and the other linked with ingredient classification. Cluster analysis produced five clusters, clearly differentiating according to the dish type, the classes of ingredients, the cooking method used and the cooking time, the role of honey in the recipe, and the moment of its incorporation into the recipe.

This study showed some relevant aspects linked with the gastronomic utilisation of honey as an ingredient in a wide variety of recipes. This work showed that the use of honey is not at all limited to desserts, but it can be used as a valuable ingredient in meat, fish, or vegetable dishes, among others. The incorporation of honey into the recipe can also vary along the confection stages, and this ingredient can have a minor or major role in the definition of the dishes' organoleptic characteristics. This evidence can be used to further extend the role of honey as a part of many other culinary preparations at home, in restaurants, or at the industrial level.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Acknowledgments

This work was supported by the FCT—Foundation for Science and Technology, I.P and by project PAGE - Paisagens Agrícolas e Alimentares com gerações de mulheres inovadoras (Ref. PRR-C05-i03-I-000217-LA7.6). Furthermore, we would like to thank the CERNAS Research Centre (Ref. UIDB/00681/2020) and the Polytechnic University of Viseu for their support. This research was developed in the ambit of project "RNAES—Rede Nacional para a Alimentação Equilibrada e Sustentável", Ref. PRR-C05-i03-I-000162.

Conflict of interest

The authors declare none conflicts of interest.

Author contributions

Sofia G. Florença: Data analysis, Writing – Original draft; Ana C. Ferrão: Writing – Original draft; Cristina A. Costa: Project administration, Funding acquisition, Writing – Review and editing; Maria João Barroca: Writing – Review and editing; Aida Silva: Writing – Review and editing; Soraia I. Pedro: Writing – Review and editing; Ofélia Anjos: Writing – Review and editing; Raquel P. F. Guiné: Design, Data collection; Data curation, Data analysis, Software, Writing – Original draft; Writing – Review and editing. All authors have read and agreed to the published version of the manuscript.

Appendix A—List of recipes

Group 1—Soups/Starters

Breaded Brie Cheese, Spicy Potatoes with Honey and Sesame, Roasted Pumpkin Recipe with Honey, Purple Carrot with Honey, Caramelized Cheese and Pear Sandwich with Honey and Ginger, Pumpking Cabotia Puree and Honey, Brie Bruschetta with Honey and Chestnuts, Roasted Brie Cheese with Honey and Rosemary, Breaded Camembert, Bruschetta, Breaded Brie Cheese, Brie with Figs Roasted in Honey and Balsamic vinegar, Chestnut and Walnut with Honey and Pepper, Brie with Honey, Carrots Sautéed with Honey, Cheese Terrine with Honey and Cashew Nuts, Ricotta and Basil Crostini, Steamy Creamy Tomato Soup, Honeyed Carrot Soup.

Group 2—Breakfast/Tea Snacks

Green Apple Toast with Brie and Honey, Banana with Oat and Honey Pancakes, Honey Bread, Orange-Cranberry Honey Butter, Shakshuka, Crusted Brie, Pear and Feta Breakfast Crostini, Honey Vanilla French Toast, Honey Citrus Iced Tea, Grilled Nectarine and Blue Cheese Bruschetta, Stuffed Baby Peppers with Yogurt and Floral Honey, Chocolate Raspberry Pancakes, Fruit Bagels with Honey Cream Cheese, Honey Smoothie Bowl, Oatmeal Almond Milk with Oranges.

Group 3—Fish Main Courses

Salmon in Honey Mustard Sauce, Gochujang Glazed Salmon with Garlic and Spinach, Honey & Garlic Salmon, Honey & Orange Roast Sea Bass with Lentils, Honey Mustard Grilled Salmon with Puy Lentils, Honey Ginger Glazed Salmon, Honey Mustard Baked Salmon with Vegetables, Creamed Honey and Miso-Glazed Salmon, Honey Glazed Salmon, Sweet Spicy Salmon with Honeyed Mango Salsa, Grouper with Avocado Ginger Peach Salsa, Honey-Ginger Glazed Salmon with Arugula Salad, Cranberry Glazed Salmon, Honey Citrus Mahi Mahi with Swiss Chard, Honey Bourbon Red Snapper, Soy Ginger Glazed Halibut with Asian Slaw, Honey Glazed Sea Bass.

Group 4—Meat Main Courses

Roasted Shank with Honey and Orange, Chicken Thighs with Mustard and Honey, Shredded Meat with Wine and Honey, Roast pork with Butter and Honey, Rib with Orange and Honey, Tender

with Mustard and Honey, Quick Steak with Mustard and Honey, Loin with Mustard and Honey, Pork Loin Mustard and Honey, Roast Chicken with Mustard and Honey, Spicy Chicken Wings with Honey and Lemon, Sticky Honey Sriracha Meatballs, Honey Steaks, Roasted Chicken Wing Drumstick with Honey and Soy Sauce and Ketchup, Herb Chicken with Honey Butter, Honey Sesame Lamb Cutlets, Korean Chili Chicken Bites, Honey Pecan Baby Back Ribs, Honey Glazed Bulgogi Beef, Honey Bronzed Brisket, Herbed Turkey Breast.

Group 5—Vegetarian Main Courses

Sesame & Honey Tofu with Rice Noodles, Honey Chile Glazed Baked Brussels Sprouts, Honey BBQ Roasted Root Vegetables, Honey Ginger Tofu and Veggie Stir Fry, Honey and Garlic Vegetarian Stir-Fry, Spring Veggie Stir-Fry, Cauliflower Steaks with Pistachios Dates and Honey Thyme Reduction, Honey-Glazed Kohlrabi with Onions and Herbs, Marinated Mushrooms with Honey and Sage, Honey Soy Tempeh with Udon, Vegetable Makhani, Honey Garlic Tofu, Cauliflower Steaks with Pistachios Dates and Honey Thyme Reduction, Honey Roasted Tomatoes and Eggplant Fettuccini with Parmesan.

Group 6—Other Main Courses

Shrimps with Honey and Lemon, Grilled Brussels Sprouts with Bacon & Honey-Balsamic Glaze, Honey Garlic Shrimp and Broccoli, Butter Soup with Shellfish and Honey Emulsion, Honey Mussels in Hoisin Sauce, Honey Beer Steamed Mussels, Halloumi with Broccoli Tabbouleh & Honey-Harissa Dressing, Honey-Brined Grilled Shrimp, Honey Cashew Chicken with Rice, Roasted Brussels Sprouts and Crispy Baked Tofu with Honey-Sesame Glaze, Honey-Glazed Shrimp, Grilled Shrimp and Spinach Salad with Honey Vinaigrette, Broiled Scallops with Honey Lime Marinade, Honey Shrimp Skewers, Grilled Honey Lime and Cumin Marinated Shrimp, Honey Baked Beans, Heirloom Tomato and Honey Gazpacho with Crab, Broiled Lobster Tails, Braised Octopus in Tomato Sauce with Roasted Fingerling Potatoes.

Group 7—Desserts

Fruit Salad with Honey and Lemon, Banana Ice Cream, Baked Pear with Honey and Lemon, Baked Apple with Honey & Cinnamon and Gorgonzola, Honey Bread Pudding, Salted Peanut Butter and Honey Ice Cream, Creamy Peach & Honey Popsicles, Roasted Berry and Honey Yogurt Popsicles, Mango Lassi Frozen Yogurt, Chocolate Peppermint Cups, Vanilla Honey-Nut Smoothie, Honey Marshmallows, Honey Flans, Honey Ice Cream, Honey Sponge Toffee, Basbousa (semolina cake).

Group 8—Bakery/Pastry

Buttery Biscuit with Honey, Banana with Raisins and Honey Cereal Bar, Oat and Honey Biscuit, Homemade Granola with Honey, Integral Oat and Honey Cookie, Apple Cake with Cinnamon and Honey and Nuts, Fried Banana Cakes with Honey, Honey Cake, Honey Bread with Milk Cream, Honey Bread Cake, Stuffed Honey Bread Cake, Oat and Honey Bread, Chocolate Cake with Honey, Honey, Orange and Almond Cake, Honey-Apple Cake, Chocolate Nut Cake, Honey Peanut Butter

Cookies, Upside-down Honey Nectarine Cake, Honey-Lime Almond Cookies, Golden Honey Pan Rolls, Honey-Peanut Butter Cookies.

Group 9—Others: Sauces and Butter

Yogurt and Honey Sauce for Salads, Homemade Pepper Sauce, Sunshine Salad Dressing, Honey Barbecue Sauce, Bold Teriyaki Sauce, Honey-Balsamic Vinaigrette, Naturally Sweetened Cranberry Sauce, Honey Butter.

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