Heliyon 10 (2024) e24056

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

Potential application of bee products in food industry: An exploratory review

Jorge L. Maicelo-Quintana [a], Katherine Reyna-Gonzales [b,*], César R. Balcázar-Zumaeta [b], Erick A. Auquiñivin-Silva [b], Efrain M. Castro-Alayo [b], Marleni Medina-Mendoza [b], Ilse S. Cayo-Colca [a], Italo Maldonado-Ramirez [c], Miguelina Z. Silva-Zuta [b]

[a] *Facultad de Ingeniería Zootecnista, Agronegocios y Biotecnología, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Calle Higos Urco 342-350-356, Chachapoyas, Amazonas, Peru*
[b] *Instituto de Investigación, Innovación y Desarrollo para el Sector Agrario y Agroindustrial (IIDAA), Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Chachapoyas 01001, Peru*
[c] *Facultad de Ingeniería de Sistemas y Mecánica, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Calle Higos Urco 342-350-356, Chachapoyas, Amazonas, Peru*

ARTICLE INFO

Keywords:
Bee products
Chemical properties
Future foods
Fat substitutes

ABSTRACT

Over the past eight years, bee products such as wax, honey, propolis, and pollen have generated intense curiosity about their potential food uses; to explore these possibilities, this review examines the nutritional benefits and notable characteristics of each product related to the food industry. While all offer distinct advantages, there are challenges to overcome, including the risk of honey contamination. Indeed, honey has excellent potential as a healthier alternative to sugar, while propolis's remarkable antibacterial and antioxidant properties can be enhanced through microencapsulation. Pollen is a versatile food with multiple applications in various products. In addition, the addition of beeswax to oleogels and its use as a coating demonstrate significant improvements in the quality and preservation of environmentally sustainable foods over time. This study demonstrates that bee products and apitherapy are essential for sustainable future food and innovative medical treatments.

1. Introduction

In the food industry, the constant search for innovative and sustainable solutions to improve food quality, safety, and functionality has led to increasing attention to bee products, such as wax, propolis, honey, and pollen [1,2]. These products obtained from the work

* Corresponding author. Instituto de Investigación, Innovación y Desarrollo para el Sector Agrario y Agroindustrial (IIDAA), Facultad de Ingeniería y Ciencias Agrarias, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Calle Higos Urco 342-350-356, Chachapoyas, 01001, Peru.

E-mail addresses: j.maicelo@untrm.edu.pe (J.L. Maicelo-Quintana), 7702961920@untrm.edu.pe (K. Reyna-Gonzales), cesar.balcazar@untrm.edu.pe (C.R. Balcázar-Zumaeta), Erick.Auquinivin@untrm.edu.pe (E.A. Auquiñivin-Silva), Efrain.castro@untrm.edu.pe (E.M. Castro-Alayo), marleni.medina@untrm.edu.pe (M. Medina-Mendoza), icayo.fizab@untrm.edu.pe (I.S. Cayo-Colca), italo.Maldonado@untrm.edu.pe (I. Maldonado-Ramirez), miguelina.silva@untrm.edu.pe (M.Z. Silva-Zuta).

https://doi.org/10.1016/j.heliyon.2024.e24056
Received 3 October 2023; Received in revised form 8 December 2023; Accepted 3 January 2024
Available online 6 January 2024
2405-8440/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

of bees have a unique chemical composition and bioactive properties with great potential to replace sweeteners, preservatives, coatings, and fat substitutes of chemical origin in the modern food industry [3].

In an environment where society is striving to reduce the consumption of added sugar and replace artificial ingredients with healthier alternatives [4], the incorporation of bee products into food products is emerging as a promising strategy [5]. The demand for natural sweeteners has arisen due to concerns about the adverse effects of excess sugar on health and the increase in chronic diseases [4].

Likewise, to fully exploit the potential of bee products in the food industry, a detailed knowledge of their chemical composition, functional properties, and multiple applications is essential [6,7]. Honey, pollen, propolis, and wax have not only unique nutritional content but also natural antioxidant, antibacterial, and antiseptic properties, which play an essential role in improving food quality and prolonging shelf life [8,9].

Due to the relevance of bee products in the current food industry landscape, it is necessary to identify how these products can be effectively incorporated into a variety of food products, providing natural solutions that improve not only nutritional value but also enhance sensory aspects such as flavor and texture, and contribute to food safety. To this end, a systematic search of the literature used for the review was conducted, covering articles related to honey, wax, propolis, and bee pollen. The search covered an interval of the last eight years and included topics related to nutrition and human health, biotechnology, food toxicology, food chemistry, and packaging technology.

Therefore, this review aims to report current knowledge and identify specific opportunities for practical applications of bee products in food improvement. This review aims to provide a solid foundation for future research and technological development in the food industry and to promote the adoption of healthier and more sustainable alternatives to meet the changing needs of society.

2. Chemical properties of bee products

The composition of bee products depends mainly on their floral origin and external factors such as beekeeping manipulations, packaging, storage conditions [10] and above all on the different chemical reactions (Fig. 1) through which honey, wax, pollen and propolis go through, involving processes such as oxidation, fermentation and hydrolysis [11,12] (Table 1).

2.1. *Bee honey*

Honey, in general, consists of about 200 components, mainly sugars; 75 % are monosaccharides, 10%–15 % are disaccharides with traces of other sugars [18], oligosaccharides and traces of proteins were also found [43]. Low & Sporns [44], with gas chromatography technique, identified 16 polysaccharides and 11 disaccharides such as maltose, turanose, sucrose, palatinose, cellobiose, isomaltose, neotrehalose, nigerose in honey. However, various flowers in the vicinity of bee hives can affect the sugar composition of honey, as each flower harbors different proportions of glucose and fructose [18,45]. There are also other varieties of sugars, such as sucrose, being detected in small amounts [46]. In this sense, the interaction between the different sugar components plays a fundamental role

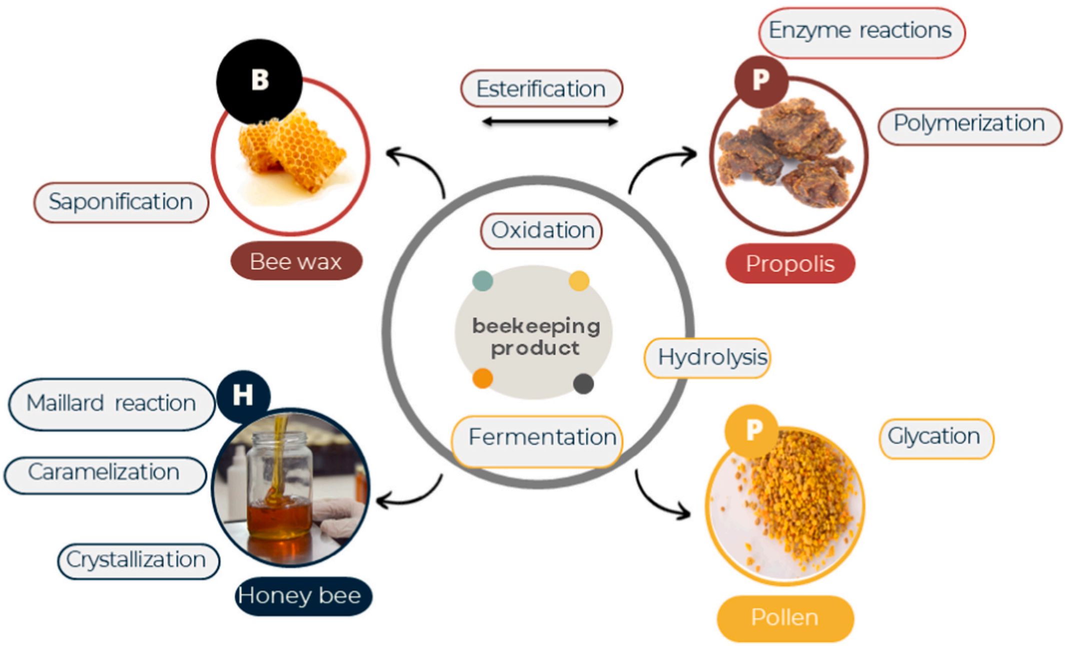

Fig. 1. Reactions involved in the production of beekeeping products.

Table 1
Reported chemical composition of beekeeping products.

Family	Components	Beekeeping products				References
		Honey	Pollen	Propolis	Wax	
Aminoacids	Proline	0.01 % a 0.05 %	0.4 % a 1 %	ND	ND	[6,13–17]
	Leucine	0.01 %	0.2 % a 0.4 %			
	Alanine					
	Arginine	ND	0,007 % a 1,13 %			
	Tyrosine		0,002 % a 1,06 %			
Sugars	Glucose	22 % a 38 %	6 % a 10 %	–	–	[13,17–21]
	Fructose	28 % a 44 %	13 % a 20 %			
	Sucrose	0.2 % a 5 %	14 % a 19 %			
	Others	0.1 % a 8 %	1 % a 3 %			
Proteins	Diastase	0.2 % a 2 %	10 % a 40 %	7,28 % a 9,41 %	–	[22–27]
	Invertase					
	Glucose oxidase					
Minerals	Calcium	0.03 %	0.02 % a 0.58 %	0.01 % a 0.1 %	ND	[13,14,17,23,28–33]
	Magnesium	0.01 %	0.02 % a 0.47 %		1.8 % a 2.7 %	
	Potassium	0.1 % a 0.4 %	0.25 % a 2 %		7.8 % a 9.9 %	
	Phosphorus	0.01 % a 0.06 %	0.08 % a 0.96 %		4.5 % a 5.06 %	
	Other	0.4 %	0.02 % a 0.3 %		0.026 % a 0.084 %	
Flavonoids		ND	0.2 % a 3.2 %	1 % a 6 %	–	[14–16,21,23,34–36]
Vitamins	Ascorbic acid	0.2 %	0.02 % a 0.7 %	ND	–	[6,13,15,23,32,35,37]
	Riboflavin	0.06 %				
	Niacin	ND				
	other	0.08 %				
Organic acids	Citric acid°	0.1 % a 0.5 %	1 %	–	–	[14,26,36,38]
	Malic acid					
	Lactic acid					
	Gallic acid					
	Palmitic acid					
Lipids	Fatty acids	ND	–	–	5 % a 18 %	[19,24,28,39–42]
	Hydrocarbons				11 % a 28 %	
	Phospholipids				4 % a 12 %	

during storage, leading to various chemical reactions, such as the formation of solid crystals in the liquid, resulting in a thicker and more granular texture due to environmental factors, such as temperature and humidity [47,48].

On the other hand, it is worth mentioning that caramelization and Maillard reaction may be present in bee honey during storage. The Maillard reaction promotes a reduction in the nutritional value of foods by destroying essential amino acids such as the ε-amino group of lysine, which reacts with sugars and other amino acids such as L-arginine and L-histidine [49]. These reactions cause the decomposition of sugars and the formation of aromatic and dark-colored compounds [50]. Consequently, the nutritional value of honey can be affected because these reactions reduce its nutrient content in foods [51,52]. It is essential to mention these reactions, as they play an important role in the transformation of honey.

In addition to the predominant sugars, another important component is amino acids. Honey contains amino acids vital for human health; bees collect nectar from flowers and initiate a complex process in the hive; enzymes in their saliva break down the sugars in the nectar and form simpler components such as amino acids [10]. These amino acids compose the nutritional profile of bee honey, an elixir that stimulates immunity [53]. Amino acids in honey contribute to protein synthesis and hormonal regulation in the body and provide energy. The vitamin and mineral content is also essential to understand its chemical composition. Calcium, magnesium, potassium, vitamin E, C, and others [13] are found in honey and are helpful for the immune system as they provide essential nutrients and antioxidant properties, thus contributing to the maintenance of health [10]. Diastase is an enzyme that can break down sugars into simpler components in proteins. The diastase number is a measure of diastase enzyme activity. It is used to evaluate the quality of honey and other honey-containing foods [54].

Honey has antibacterial properties due to the formation of hydrogen peroxide by enzymatic and non-peroxide activity based on phenolic and organic acids. These properties vary according to the floral source of honey [55]. In addition, the antioxidant elements in honey help to eliminate bacterial infections and the production of antibodies in the immune system. The presence of phenols and flavonoids in honey is closely related to its antioxidant properties [56].

2.1.1. Adulteration and contamination

Due to the variety of compounds that give it its unique properties and the high demand for its consumption, there are challenges in preventing its Adulteration [57]. For example, honey production in South Africa is hampered by the fact that 50 % of its demand is imported [58].

Alarming concerns remain regarding adulterated honey, which often contains artificial sweeteners, corn syrup or banana flour, wheat or indirectly through bee feeding [47], and honey contaminated by the presence of toxic metal concentrations [59]. Yohannes et al. [60] reported metal concentrations with an abundance of iron followed by cadmium, a major contributor being the geographical origin of honey; similarly, Tibebe et al. [61] mentioned that despite the presence of iron in considerable quantities, followed by Ni, Zn, Co, Mn, and Cu in honey, its physicochemical properties did not undergo any noticeable changes, its pH was from 4.11 to 4.33, electrical conductivity from 0.10 to 0.29 mscm-1 and ash content from 0.17 to 0.46 %. This result is consistent with other studies that indicate that, under normal conditions, honey has a pH between 3 and 5 [47]. According to the authors, despite the presence of heavy metals, honey itself is still safe for human consumption. However, to minimize contamination in honey, it is recommended to keep bee colonies away from chemical industries, contaminated water sources, and other potential sources of contamination to minimize impurities found in honey.

Color and aroma visualization can indicate honey quality, but they could also be helpful indicators of prolonged storage. It would be interesting to explore techniques that detect the quality of honey and its storage time. Why not take full advantage of chemical reactions to detect compounds that could provide information on honey quality and storage? These measurements could serve as a detector of poor-quality products or prolonged storage of honey.

2.2. Propolis

Propolis is a highly complex material of natural constituents containing resins, waxes, aromatic compounds, pollen, and other organic compounds [62–65]. More than 300 components have been identified during the chemical characterization of propolis types [66].

The presence of amino acids in propolis is because they are obtained from flowers and even by the same metabolism of bees (Table 1) [67]. On the other hand, the flavonoids in this apiculture product are since this bee product is elaborated from excretions or secretions of vegetable origin, such as buds and barks [15], in turn causing different chemical reactions such as polymerization in the presence of oxygen and light producing compounds such as tannins [68]; enzymatic reactions producing compounds such as quinones and lactones [69] and esterification reacting with alcohols to form esters [16,70]. These reactions characterize the product as antimicrobial and antioxidant [63–65]. During the harvesting and processing of propolis by bees, beta-glucosidase, an enzyme that hydrolyzes the heterosides to aglycones, is secreted, thus improving the pharmacological action of the product and causing physicochemical changes in the product [71]. The presence of fatty acids in propolis is not a defining feature, although they have been identified. The fatty acids in propolis, which come mainly from the wax, vary according to the plant source [10,71].

In propolis, it is not only the antibacterial properties that make it attractive to the food industry, with its high concentration of amino acids and other nutrients, propolis could be a valuable resource for human nutrition; in fact, it contains 20 of the 22 amino acids that make up human proteins [72–74].

2.3. Pollen

Bees prepare their pollen by mixing their secretions with pollen collected from flowers, resulting in granules containing thousands of pollen grains approximately 1.4 mm–4 mm in size [40]. It is the primary source of nutrients for bees due to its high composition [75,76]. Bee pollen provides many health benefits to humans due to its abundance of proteins, carbohydrates, dietary fiber, and mainly polyunsaturated fatty acids. In addition, this product is rich in various vitamins and minerals such as K, Mg, Ca, Na, Fe, and Cu, as well as other valuable bioactive compounds such as phenolic acids in low amounts, flavonoids in high amounts, and phytosterols [13,77]. Nevertheless, Laaroussi et al. [7] mention that it is difficult to identify these beneficial ingredients due to their double-layered protective structure that protects against external factors such as climate, pollution, and microorganisms. In addition to their high molecular weight and similar polarity among sugars, they prevent the release of vitamins and minerals when used in foods [19]. According to research by Campos et al. [78] and Thakur & Nanda [79], daily administration of 40 g of pollen reduced cholesterol levels and improved human cardiovascular health; this may be due to the high levels of vitamins found in pollen [80]. It is worth noting that daily intake requirements may vary depending on the unique composition of bee pollen [81].

Alternatively, recent studies provide interesting information about the lipid composition of pollen. It varies greatly depending on the botanical origin. In the study by Aylanc et al. [28] pollen collected from *Plantago* sp contained only 4.2 $g.100\ g^{-1}$ of lipids, whereas pollen collected from Crepis capillaris contained almost twice as much, 9.3 $g.100\ g^{-1}$. Furthermore, Mărgăoan et al. [82] observed the presence of fourteen different fatty acids in pollen extracts, with a high amount of α-linolenic acid ranging from 21.53 % in samples from Turkey to 43.26 % in samples from Romania. Turkish samples contained about 13.54 % linoleic acid. Romanian samples contained 38.29 % linoleic acid. Palmitic acid ranged from 16.25 % in the Turkish pollen sample to 28.66 % in the Romanian sample. Oleic acid was found to average 2.96 % in the Turkish samples and a higher value of 14.88 % in Romania. Finally, stearic acid ranged from 2.06 % to 5.75 % in the Romanian pollen sample.

Pollen enzymes in the environment and within the bodies of organisms, such as bees, can catalyze hydrolysis reactions upon contact with pollen [23,34,35]. The action of enzymes, either in the natural environment or during digestion, leads to hydrolysis of the pollen, which is necessary to extract valuable nutrients [10,71]. This decomposition process ensures the release of the nutrients contained in the pollen and allows organisms to reap the benefits.

Variations in the nutritional content of the pollen, depending on its source, can be used as the key to identifying biomarkers associated with better health. Differences between pollen regions can help determine how much nutritional quality is affected. Given these changes, in vitro testing is critical to understand their benefits and potential health applications better. This approach could provide valuable information on how pollen affects health in different regions, leading to a clearer understanding of its properties and thus helping to develop strategies to harness its benefits more effectively.

2.4. Beeswax

The absence of flavonoids in beeswax is attributed to the fact that it is produced by bees, rather than collected from plants. [4], its composition is mainly highlighted by free hydrocarbons and fatty acids, linear wax monoesters and hydroxymonoesters, complex acids [83,84] and long-chain fatty acid esters capable of crystallizing and forming a three-dimensional network that traps the liquid oil [85]. When beeswax is in contact with an alkaline solution, such as potassium or sodium hydroxide [86] a chemical reaction known as saponification occurs, the beeswax esters hydrolyze to create fatty acid salts and glycerol [87]. In addition, esterification, a reaction where fatty acids in beeswax combine with alcohols to form esters, can be observed [88].

3. Uses of bee products in the food industry

Different uses of bee products have been reported, and are highlighted in Table 2.

3.1. Sweeteners

Bee products offer a wide range of possibilities for food incorporation. Their unique properties, such as taste, nutritional value and functional properties, have attracted the interest of consumers and food manufacturers. Currently, sugar consumption in sugar-sweetened beverages is a significant public health problem that has gained popularity in recent years [123] due to the increase in type 2 diabetes [124,125] and the consumption of 500 calories per day on average from added sugar alone [18]. Therefore, product reformulation by partial or total sugar substitution is the most studied strategy in most investigated food categories, such as bakery, chocolate, ice cream and desserts, jams, and jellies [126]. Because of this, natural sweeteners based on bee honey have come to be researched and developed as alternatives to sugar [54,89].

Honey is a unique sweetening agent humans can use without processing because it has important nutritional and medicinal benefits [127–129]. As a natural sweetener, it needs to be researched at present. However, Engin Gündoğdu et al. [71] mention that in food production, the use of honey as a natural sweetener could meet the needs of customers who focus on natural foods and new product formulations capable of satisfying low glycemic index dietary regimens [90,91], thanks to its nutritional properties and aromatic profile and chemical composition [130–132]. Furthermore, in their study, Mutlu et al. [54] investigated the possibility of producing healthy jelly candies for children by using honey as a sugar substitute and incorporating fruit juices. The study found that the cold mixing technique resulted in a higher diastase number, and the incorporation of fruit juices significantly affected the jelly candies' pH, acidity, and diastase number. In addition, these authors found a significant difference in the sugar and proline profile between jellies made with honey and those made with sugar. These findings suggest that honey as a sweetener can produce more appealing and healthier jelly candies and other products for consumers in the bakery and beverage—industries due to its multiple components.

3.2. Food preservatives

The versatility of honey goes beyond its sweetness and dietary functions. Thanks to its bioactive and antimicrobial activity and its low pH, it can be used as a natural preservative in foods, helping to prevent spoilage [107,133]. Thus, due to non-peroxide compounds, it is more effective against Gram-negative bacteria [134] and able to inhibit the growth of pathogenic microorganisms and fungi such as *E. coli*, *Bacillus cereus* and so forth [100]. In many scientific studies, propolis has shown significant antibacterial activity against *E. coli*, *S. aureus*, *Streptococcus species*, *Salmonella typhi*, *Enterococcus* sp., *Bacillus* sp., and *Pseudomonas aeruginosa* [72]. The antibacterial properties of propolis are due to the different ways it acts on Gram-positive and Gram-negative bacteria. Propolis stands out for its greater efficacy against Gram-positive bacteria than Gram-negative bacteria, attacking cell membranes, weakening them, and making them more susceptible to antimicrobial treatments [135,136].

The high concentration of sugar in honey exerts an osmotic pressure on bacterial cells, inducing the outflow of water from these cells. Recent studies have shown that high osmotic pressure can inhibit biofilm formation in bacteria such as *Pseudomonas aeruginosa* and *Staphylococcus aureus*. However, preserving food can be challenging and although honey is often considered a reliable option, it is not always the best choice compared to chemical preservatives. It is essential to remember that the stability and efficacy of honey varies depending on the food to be preserved. Therefore, each situation must be evaluated separately to determine if honey is a suitable preservation method.

Propolis can be used as a preservative in foods such as fruit juices [137], meats [138], fruits [139], and dairy products [140]. Its antiseptic properties have been demonstrated against a wide variety of microorganisms such as bacteria, fungi, viruses, yeasts, and parasites [64,141,142], in addition to possessing antifungal activity against *Aspergillus niger* and *Penicillium* spp [143]. The concentration of phenolic acids and flavonoids in propolis extract is essential in inhibiting the growth of bacteria, molds, and yeasts in food products [64].

Bacterial cell membranes are weakened when attacked by propolis, making it an excellent tool against Gram-positive bacteria [144,145]. One of its many strengths is that it can prevent the creation of biofilms, which are defensive structures that Gram-positive bacteria often use to resist antimicrobial treatments [105]. Because of the water-insoluble serous substance, bitter taste and its contamination with external agents, propolis must undergo purification processes [146,147] or maceration processes using aqueous ethanol as a solvent for extraction [148]. The efficacy of hydroalcoholic propolis extracts (at various concentrations) in inhibiting fungal growth has been demonstrated by external application to various foods [24]. For this reason, using methods for propolis

Table 2
Main uses of bee products in foodstuffs.

Function	Honey	Pollen	Propolis	Wax	References
Sweeteners	It is used in liquid form as a sweetener in beverages, as a coating in bakery products, and in molten form as a component in preparing dressings, desserts, and industrial products.	–	–	–	[54,89–93]
nutritional supplements		As a food ingredient, providing nutrients and flavor to various products.	–	–	[7,94–99]
Antioxidant agent-			It is applied as an ethanolic extract and by encapsulation. These methods allow the precise and efficient incorporation of propolis in food formulations.	–	[14,67,100–102]
Preservatives	It is added directly to food to maintain quality and prolong shelf life.	–		–	[34,100,103–107]
Fat substitutes	–	–	–	It is used as oleogels, hybrid gels, and hydrogels as substitutes for traditional fats. These approaches enable the formulation of foods with alternative lipid profiles and additional health benefits.	[39,108–113]
Coating	–		–	It is used in a molten state to impart a protective surface and improve the appearance of food.	[113–122]

extraction is crucial to eliminate the earthy odor, mainly when propolis is applied in food formulation [149,150] of animal origin to protect it against microbiological spoilage [151].

Due to the rejection of chemical preservatives, there has been a growing interest in natural preservatives in food, and propolis is an interesting alternative to consider in new food technology applications [135,136]. Propolis extracts are a promising future for the food industry as they offer solutions to many problems encountered while storing different food products, such as preservatives in meat products, nutritional supplements, and so forth. Currently, soft drinks and beverages have a high concentration of preservatives such as sorbate salts and sugar [106,152,153] harmful to health.

Several researches show the use of propolis as a natural preservative in the processing of various foods; for example, in the incorporation of different propolis extracts in milk drinks where it improved their antioxidant capacities [154]; or in traditional Turkish sausages, where it was effective against oxidation, maintaining quality parameters [155,156]. These results demonstrate that propolis can be an effective alternative to traditional chemical preservatives, representing healthy and natural options for the food industry.

In addition, lipid oxidation in meat products is well recognized, due to the presence of free radicals damaging the cells, causing rancidity, affecting the organoleptic properties and nutritional value of the food [157]. By playing an essential role in preventing lipid oxidation, propolis acts as a natural antioxidant that preserves food quality and extends shelf life [158]. However, certain factors need to be addressed before propolis can be widely used as a preservative agent. Different food matrices and storage conditions should be evaluated to ensure the safety and stability of propolis. In addition, it is important to note that not all applications will be practical at the same concentration, as propolis interacts with other ingredients and affects sensory quality. Due to geographical and climatic differences, the propolis mixture is subject to variations that may affect its shelf life. Formulating consistent propolis extracts is challenging, and further studies are recommended to determine best practices for use as a preservative in the food industry.

According to research, several food products have been successfully preserved using propolis, so the different concentrations of propolis used are an important factor in preventing the growth of microorganisms and preservation [159]. Several studies have shown that the efficacy of propolis as an antimicrobial agent may vary depending on the concentration used. Vasilaki et al. [106] demonstrated that using higher concentrations of propolis extract is more effective in reducing the microbial load in non-carbonated beverages by improving their antioxidant activity and total phenols. In addition, the concentration of propolis extract has been related to its efficacy in prolonging the shelf life of sausages, as noted by Ref. [160], where it was found that 2 % propolis extract prolonged the shelf life of sausages for 56 days.

Mazamba et al. [161] analyzed the use of propolis to preserve red tilapia fillets. Propolis was applied in two concentrations (15 % and 30 %), which significantly reduced microbial growth and lipid oxidation at 15 % concentration, maintaining organoleptic characteristics during storage up to 20 days [140]. evaluated propolis extract as a natural preservative in marine chicken breasts at concentrations of 0 %, 4 %, 8 %, and 12 % w/w. The developed analyses showed that the 8 % concentration caused slow changes in odor and texture. It also improved the product's shelf life during 12 days of storage. However, Güngören et al. [162], when investigating the effects of propolis extracts on hot smoked vacuum-packed rainbow trout, observed that the lowest concentration of 0.25 % had no noticeable effect on the shelf life, which remained similar to the control. However, higher 1 % and 3 % concentrations were found to have a shorter shelf life, with the 1 % concentration having a longer shelf life. In particular, the 3 % concentration significantly affected microbiological and chemical properties, indicating the potential of propolis as an antimicrobial and antioxidant agent. Product aroma and flavor were negatively affected. Interestingly, the 1 % concentration showed more robust attributes regarding color, aroma, and overall attractiveness. These findings imply that the 1 % concentration may be ideal for preserving the organoleptic excellence of the product.

The variability in results from different studies highlights the need for a clear consensus and further research. Propolis concentrations in foods focus on its antimicrobial capacity and how these concentrations affect the organoleptic characteristics of the food and consumer acceptability.

Fig. 2 shows the process of elaborating ethanol extract of propolis, according to different investigations [163–165].

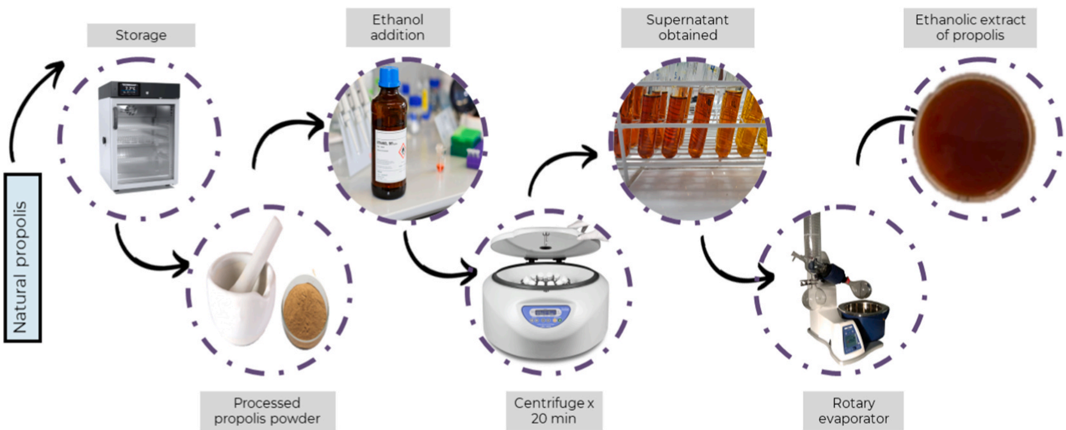

Fig. 2. Elaboration process of propolis ethanol extract of propolis.

Propolis is also helpful in forming microcapsules widely used in the food industry [166]. Encapsulation technology emerges as a possible solution to improve the application of bioactive compounds of propolis in the pharmaceutical and food industries [156]. It serves for processing and protection in foods that are unstable in the environment, improving their physicochemical properties and allowing, in turn, to potentiate flavors and odors, among others. Encapsulated and microencapsulated active ingredients can be bioactive molecules (flavoring agents, sweeteners, colorants, and vitamins) or living cells such as probiotics [167].

Microencapsulation consists of storing an active ingredient or a mixture of substances, which can be small particles, liquid or gaseous, inside a coating or layer that provides protection against external components (water, heat); this is why microencapsulation is a valuable technology that prolongs shelf life, masking undesirable odors and flavors [166]. Encapsulation uses several processing technologies, primarily based on spray drying, freeze drying, vacuum drying, etc. [168]. Vacuum encapsulation is a fast and economical technique compared to other methods, such as freeze-drying, since it works at a temperature above the solvent's freezing point [169,170]. For example, Piedrahíta Márquez et al. [171] encapsulated propolis extracts with the spray drying method in order to study the effects of edible chitosan and propolis coatings on the stability of chilled and vacuum-packed cachama fillets, reporting that the encapsulated propolis coatings increased shelf life, preventing microbiological proliferation and improving the texture profile. Likewise, it is mentioned that spray drying was the most used technique for the encapsulation of bioactive compounds of products such as propolis due to its ability to preserve the bioactive properties [172]. However, it should be noted that the choice of encapsulation techniques depends on factors such as the type of compound to be encapsulated, the stability of the compound throughout encapsulation and the desired properties of the final product [173].

The re-evaluation of topical systems and their impact on biofilms is crucial in understanding antimicrobial agents' efficacy. In this context, the importance of conducting studies to determine the optimal concentration to inhibit microbial growth and biofilm formation without negatively affecting the product's sensory qualities is emphasized. Higher levels of propolis may effectively inhibit microorganisms but may compromise sensory attributes. This highlights the need for careful consideration when selecting concentrations. It is essential to consider each product's characteristics and to find a balance between the concentration needed to conserve and preserve organoleptic properties.

3.3. Nutritional supplements

There is considerable interest in using pollen in food systems as a functional ingredient to enrich product quality characteristics [80, 174]. It has been used to enrich yogurt, cheese, bread, and fermented beverages as a biotechnofunctional ingredient with strong antioxidant and antimicrobial activities, improving the nutritional and functional characteristics of the final products [175]. Krystyjan et al. [96] mention that bee pollen can be used as a fortifier in foods such as cookies, as it increases their chemical and physical properties. However, Sokmen et al. [97] point out that with the addition of pollen, cookies have low amount of bioactive compounds due to the external layer (exine) of the pollen, which act as a protective barrier that preserves the bioactive compounds inside the pollen and provides chemical and enzymatic resistance hindering the release [94]. Although Krystyjan et al. [96] recommends that pollen enriches flour-based foods such as cookies, and improves their chemical and physical properties, there is debate as to how effective this enrichment actually is in releasing beneficial compounds to the consumer. Ares et al. [94] mentions that this difficulty between retention and release of bioactive compounds raises doubts about the real use of pollen to improve the properties of the final product.

3.4. Fat substitutes

Another contribution of bees to the food industry is beeswax. Fats and oils are essential nutrients in our diet and are widely used in food formulation for their nutritional value, sensory quality, and textural effect [176,177]. However, the negative impact of saturated and trans fatty acids has prompted researchers to search for substitutes with similar properties to solid fats [178], suggesting that these substitutes are safe and healthy, with good texture, plasticity, and shelf life [179].

Nowadays, substitutes such as oleogels, with viscoelastic properties similar to semi-solid fats, are gradually being applied in the food industry and other fields [180,181], is made by converting edible liquid oil into a gel-like solid structure with the help of various oleogels such as vegetable waxes, phytosterols, alcohols, fatty acid esters and phospholipids [182]. Natural wax-based oleogels can act as structuring agents in fatty foods such as margarine, chocolate, meat, and dairy products [177]. Combining liquid oil and beeswax in an oleogel can result in a semi-solid matrix that can effectively retain encapsulated bioactive compounds during storage [13].

In the meat industry, oleogels are considered one of the most novel approaches that help to improve the nutritional properties of products [177,183] and replace the fatty acids that naturally confer organoleptic properties by giving appearance and texture characteristics [184]. Zhang et al. [181] highlighted the use of beeswax as an oleogel agent to improve the rheological properties of surimi sausages. Their study revealed that the addition of wax to sausages not only improves the textural properties, but also contributes to a denser gel structure. This improvement is attributed to the oleogel solids filling the voids in the protein network, generating a more compact structure in the surimi gel [185].

While the findings of Zhang et al. [181] indicate that beeswax helps to improve the textural properties of surimi sausage, Moghtadaei et al. [186] suggests a different perspective. Moghtadaei et al. [186] observed that patties absorbed less fat when infused with beeswax, and elucidated this phenomenon through the gelling properties of beeswax, which forms a three-dimensional network in the oil, limiting its ability to absorb fat during frying.

These differences highlight the complexity of the role of beeswax in different food matrices. While Zhang et al. [181] focused on improving the texture of surimi sausage, Moghtadaei et al. [186] emphasized the reduction of fat absorption and changes in texture and color properties of hamburger. The differences in the results highlight the need to better understand how it interacts. Beeswax forms a three-dimensional network in the oil, which reduces its ability to absorb fat during frying. In addition, the addition of beeswax reduced the toughness, stickiness, and chewiness of the beef patties. This is because beeswax has a lower hardness than animal fat, affecting meat's textural properties [112]. Variations were also observed in different color parameters of beef patties due to the size of lipid globules in the meat and the instability of the oil gel during cooking. Beeswax can affect the distribution and size of meat lipid globules, which in turn affects the color of the patty [186].

In the confectionery industry, the application of oleogels has become a recent trend to improve physical and functional properties [187], developing heat-resistant chocolates, fat bloom control during storage, and as a substitute in cocoa butter [178,188]. Ghorghi et al. [39] report that oleogel-based hybrid gels from beeswax in the formulation of a compound chocolate could be a promising alternative that replaces hydrogenated vegetable oils in the production of chocolates, improving their texture, viscosity, and stability by reducing fat and sugar bloom [188–190]. Additionally, the incorporation of beeswax oleogels prevents fat and sugar bloom in functional chocolates because it promotes the transformation of monoglyceride crystals and the structural reorganization of crystals, increasing their hardness [85]. When beeswax crystallizes in oil, a granular gel is formed due to the interaction of van der Waals crystals and crystal aggregates, immobilizing the liquid oil [191], affecting the crystal configuration [108]. Importantly, oleogel in chocolate can generate the same crystal shape as dark chocolate, providing a stable crystal lattice and preventing bloom [178]. It is evident that despite the growing importance of oleogel research with beeswaxes in chocolates, it still needs to be improved. Further studies are needed to determine whether oleogels affect the melting point and the physical stability and bloom of chocolate during different storage and processing conditions.

3.5. Coatings

Beeswax as a coating is noted for its ability to preserve food freshness and quality by providing a physical barrier against moisture loss, oxidation, and bacterial contamination [116]. In this regard, beeswax-based coatings offer great potential to reduce food loss, such as in pears [120], mandarins [192], tomatoes [193,194], mangoes [121], guavas [116], citrus fruits [195], and in industrialized products such as cheeses and meat sausages [115]. These beeswax-based coatings act as a protective layer on the surface of fruits and vegetables, preserving their freshness and quality by minimizing moisture loss, oxidation, and bacterial contamination [117]. Ultimately, by extending the shelf life of these perishable foods, beeswax coatings help prevent their wastage and contribute to food safety and sustainability [120]; such coatings are applied directly on the food surface and consist of thin membranes that are invisible to the naked eye [116].

It is important to promote research on the individual components present in beeswax and how they influence its antimicrobial activity. In addition, the different environmental and geographical conditions of beeswax production should be taken into account to understand their differences. These studies will help to fully exploit the potential of beeswax for various industrial applications such as in oleogels to realize its full potential. By doing so, it will be possible to optimize compositions, fully understand the properties and characteristics of the product, evaluate its stability and durability, as well as open new opportunities for its application in various disciplines such as food industry, environmental, agriculture, among others.

4. Food of the future and medicinal treatments

In a world characterized by continued population growth, depletion of natural resources, and the urgent need to address climate change, the search for sustainable and nutritious food has become a global imperative global [196,197]. In this context, bee products become an invaluable resource that can play a central role in the nutrition of the future. In addition to being rich in taste and texture, these bee products offer unique promises, as they provide nutritional sources rich in antioxidants, vitamins, and essential minerals and are also in line with the growing awareness of sustainability and environmental ethics.

Pollination is a fundamental food production process, and beekeeping can contribute to crop pollination, making it an important activity for future food production [198,199]. However, to ensure the production of these products, it is necessary to promote sustainable beekeeping and bee conservation.

4.1. Trends in the use of bee products in the food and beverage industry

Functional foods and nutraceuticals produced from bee products include food supplements, energy drinks, and sports foods [42]. Combining honey and propolis in the production of ice cream, sorbets, and in the production of alternative dairy products such as royal jelly or yogurt based on almond, coconut, or soy milk sweetened with honey or royal jelly can lead to healthier product choices due to the sweet taste, textural restorative capacity and nutritional value of honey, royal jelly and propolis [71].

Developing fermented beverages such as kombucha or probiotic beverages, including bee products, to improve taste and nutritional quality would be an innovation, as they contain beneficial microorganisms that can contribute to fermentation [200]. The development of herbal beverages sweetened with honey and enriched with propolis or pollen is an interesting trend in the food and beverage industry because it combines the advantages of bee products such as antibacterial and anti-inflammatory properties of propolis, honey as a natural sweetener and pollen as enrichment of proteins, vitamins, minerals and antioxidants [71]. The best of beekeeping and herbal medicine can be combined in this drink.

On the other hand, dehydrated foods using bee products, such as fruits with crystallized honey or nuts with propolis, can be other alternatives to obtain healthy and delicious snacks since honey and propolis are rich in natural carbohydrates, antioxidants, and other compounds that promote health [201]. Combining them with fruits and nuts in a dehydrated diet creates a snack that provides sustained energy and essential nutrients. Beeswax, on the other hand, is a natural and biodegradable material that can be used in the production of eco-friendly containers and packaging, such as food wrappers, storage bags, and cosmetic packaging [202–205], in the manufacture of candies and chocolate as a coating agent and to give shine to the final product, in the manufacture of edible candles, which can be used as decoration in cakes and desserts or as an ingredient in the manufacture of bakery products, such as bread and cookies, helping to improve the texture and preservation of the product [206,207].

Sustainable beekeeping and bee protection are fundamental to ensure future food production. They involve practices that respect the environment and the welfare of bees, thus ensuring the production of high-quality bee products and crop pollination [208]. Protecting bees is crucial as they are essential pollinators, and their decline can have severe consequences for food production [119, 207].

4.2. Apitherapy and its possible applications in modern medicine

Apitherapy is an alternative therapy that uses bee products, such as honey, bee venom, and royal jelly, to treat various diseases and ailments [209]. Although apitherapy has been used since ancient times, its use in modern medicine is still controversial and debated.

However, several studies suggest that apitherapy may have applications in medicine in the future. Although bee venom has not been extensively studied at this time, this product contains a substance called melittin that has analgesic and anti-inflammatory properties [210–212]. While some research suggests that bee venom apitherapy may be effective in the treatment of chronic pain, such as arthritis, fibromyalgia and against cancer [213], bee venom apitherapy may be effective in the treatment of multiple diseases.

5. Conclusions and prospects

Bee products, such as honey, propolis, pollen, and beeswax, offer remarkable benefits to human health due to their unique nutritional properties and characteristics. However, despite their contribution to the food industry, concerns persist about possible contamination and adulteration in the composition of honey. These challenges demand effective regulation and quality control to preserve the integrity of these products.

This review covers several areas of study, highlighting the potential health benefits and limitations of pollen as a biotechnofunctional ingredient and the various aspects of honey quality and storage. The sweetening and preservative properties of honey are emphasized, and further research is needed to understand its applications. In addition, it is stressed that it is crucial to maintain the sensory properties of products by carefully considering the concentration of propolis and to promote the exploration of the applications of beeswax components in various industries, with particular attention to optimizing their potential through factors such as the climate and air of the geographical environment where beekeeping is practiced. The formation of oleogels, in combination with beeswax, presents promising options for meat products, chocolates, and other foods. It is also perceived as an effective solution to extend the shelf life and promote the sustainability of perishable foods by using beeswax as a coating, thus preserving their freshness and quality.

These researched bee products are a great resource for finding sustainable and nutritious foods. Their nutritional contribution to the food industry indicates improvements in various innovative foods' taste and nutritional quality. Also, together with apitherapy, they are critical elements of a sustainable food future and innovative medical treatments, provided they are supported by ongoing research and responsible beekeeping practices.

It is expected that research in this area will continue to advance to discover new applications and develop new technologies for producing and processing products that will allow their large-scale use in the food industry. There is a need to promote research on the individual components present in wax and honey and how they affect their antimicrobial activity. In addition, the different environmental and geographical conditions of bee product production should be considered to understand their differences. These studies will help to maximize the potential of these products in various industrial applications, optimize ingredients, gain an in-depth understanding of product performance and characteristics, evaluate stability and durability, and open new opportunities for their applications in various fields.

6. Ethics statement

Review and approval by an ethics committee was not needed for this study because this was a literature review and no new data were collected and analyzed.

Funding

The APC was financed by the Vicerrectorado de Investigación - Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas. This research was funded by the Consejo Nacional de Ciencia, Tecnología e Innovación Tecnológica- Concytec (Project: Desarrollo de chocolates oscuros resistentes al calor incorporando subproductos de miel de abeja microencapsulados, contract N° 501082378-2023 PROCIENCIA) of the Peruvian Government.

CRediT authorship contribution statement

Jorge L. Maicelo-Quintana: Supervision. **Katherine Reyna-Gonzales:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **César R. Balcázar-Zumaeta:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Formal analysis, Data curation, Conceptualization. **Erick A. Auquiñivin-Silva:** Validation, Methodology. **Efrain M. Castro-Alayo:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Marleni Medina-Mendoza:** Writing – original draft, Supervision, Funding acquisition. **Ilse S. Cayo-Colca:** Writing – review & editing, Writing – original draft, Supervision. **Italo Maldonado-Ramirez:** Resources. **Miguelina Z. Silva-Zuta:** Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors thank Proyecto C.U.I. No. 2343049: Creación de los Servicios de investigación en ingeniería de alimentos y post cosecha de la UNTRM for the facilities provided during the execution of this work.

References

[1] S. Ahmad, M.G. Campos, F. Fratini, S.Z. Altaye, J. Li, New insights into the biological and pharmaceutical properties of royal jelly, Int. J. Mol. Sci. 21 (2020) 382, https://doi.org/10.3390/ijms21020382.
[2] A. Sharma, K. Pant, D.S. Brar, A. Thakur, V. Nanda, A review on Api-products: current scenario of potential contaminants and their food safety concerns, Food Control 145 (2023) 109499, https://doi.org/10.1016/j.foodcont.2022.109499.
[3] C.I. Mureşan, D.S. Dezmirean, B.D. Marc, R. Suharoschi, O.L. Pop, A. Buttstedt, Biological properties and activities of major royal jelly proteins and their derived peptides, J. Funct.Foods 98 (2022) 105286, https://doi.org/10.1016/j.jff.2022.105286.
[4] C. Habryka, R. Socha, L. Juszczak, The effect of enriching honey with propolis on the antioxidant activity, sensory characteristics, and quality parameters, Molecules 25 (2020) 1176, https://doi.org/10.3390/molecules25051176.
[5] B.V. Batis, A.C. Tamayo, A.P. Quiala, La flora medicinal, melífera y ornamental en la agricultura suburbana: una revisión bibliográfica, Revista Científica Agroecosistemas 9 (2021) 178–186.
[6] M. Kieliszek, K. Piwowarek, A.M. Kot, S. Błażejak, A. Chlebowska-Śmigiel, I. Wolska, Pollen and bee bread as new health-oriented products: a review, Trends Food Sci. Technol. 71 (2018) 170–180, https://doi.org/10.1016/j.tifs.2017.10.021.
[7] H. Laaroussi, P. Ferreira-Santos, Z. Genisheva, M. Bakour, D. Ousaaid, A. El Ghouizi, J.A. Teixeira, B. Lyoussi, Unveiling the techno-functional and bioactive properties of bee pollen as an added-value food ingredient, Food Chem. 405 (2023) 134958, https://doi.org/10.1016/j.foodchem.2022.134958.
[8] M.X. Chua, Y.T. Cheah, W.H. Tan, D.J.C. Chan, A novel cultivation platform of duckweed (Lemna minor) via application of beeswax superhydrophobic coatings, Environ. Res. 224 (2023) 115544, https://doi.org/10.1016/j.envres.2023.115544.
[9] Á.-M. González-Montemayor, A.C. Flores-Gallegos, L.E. Serrato-Villegas, M.G. López-Pérez, J.C. Montañez-Sáenz, R. Rodríguez-Herrera, 6 - honey and syrups: healthy and natural sweeteners with functional properties, in: A.M. Grumezescu, A.M. Holban (Eds.), Natural Beverages, Academic Press, 2019, pp. 143–177, https://doi.org/10.1016/B978-0-12-816689-5.00006-7.
[10] D. Stefas, N. Gyftokostas, P. Kourelias, E. Nanou, C. Tananaki, D. Kanelis, V. Liolios, V. Kokkinos, C. Bouras, S. Couris, Honey discrimination based on the bee feeding by laser induced breakdown spectroscopy, Food Control 134 (2022) 108770, https://doi.org/10.1016/j.foodcont.2021.108770.
[11] A. Berg, H.D. McCarthy, A soy-yoghurt-honey product as a therapeutic functional food: mode of action and narrative review, Heliyon 8 (2022) e11011, https://doi.org/10.1016/j.heliyon.2022.e11011.
[12] O. Bobis, A.R. Moise, I. Ballesteros, E.S. Reyes, S.S. Durán, J. Sánchez-Sánchez, S. Cruz-Quintana, F. Giampieri, M. Battino, J.M. Alvarez-Suarez, Eucalyptus honey: quality parameters, chemical composition and health-promoting properties, Food Chem. 325 (2020) 126870, https://doi.org/10.1016/j.foodchem.2020.126870.
[13] V. Aylanc, S.I. Falcão, S. Ertosun, M. Vilas-Boas, From the hive to the table: nutrition value, digestibility and bioavailability of the dietary phytochemicals present in the bee pollen and bee bread, Trends Food Sci. Technol. 109 (2021) 464–481, https://doi.org/10.1016/j.tifs.2021.01.042.
[14] Y. Cheng, Z. Wang, W. Quan, C. Xue, T. Qu, T. Wang, Q. Chen, Z. Wang, M. Zeng, F. Qin, J. Chen, Z. He, Pine pollen: a review of its chemical composition, health effects, processing, and food applications, Trends Food Sci. Technol. 138 (2023) 599–614, https://doi.org/10.1016/j.tifs.2023.07.004.
[15] S.N.A.S. Salleh, N.A.M. Hanapiah, W.L.W. Johari, H. Ahmad, N.H. Osman, Analysis of bioactive compounds and chemical composition of Malaysian stingless bee propolis water extracts, Saudi J. Biol. Sci. 28 (2021) 6705–6710, https://doi.org/10.1016/j.sjbs.2021.07.049.
[16] M. Surek, M.M. Fachi, A. de Fátima Cobre, F.F. de Oliveira, R. Pontarolo, A.R. Crisma, W.M. de Souza, K.B. Felipe, Chemical composition, cytotoxicity, and antibacterial activity of propolis from Africanized honeybees and three different Meliponini species, J. Ethnopharmacol. 269 (2021) 113662, https://doi.org/10.1016/j.jep.2020.113662.
[17] G.-W. Zammit Young, R. Blundell, A review on the phytochemical composition and health applications of honey, Heliyon 9 (2023) e12507, https://doi.org/10.1016/j.heliyon.2022.e12507.
[18] S. Arshad, T. Rehman, S. Saif, M.S.R. Rajoka, M.M.A.N. Ranjha, A. Hassoun, J. Cropotova, M. Trif, A. Younas, R.M. Aadil, Replacement of refined sugar by natural sweeteners: focus on potential health benefits, Heliyon 8 (2022) e10711, https://doi.org/10.1016/j.heliyon.2022.e10711.
[19] Q.-Q. Li, K. Wang, M.C. Marcucci, A.C.H.F. Sawaya, L. Hu, X.-F. Xue, L.-M. Wu, F.-L. Hu, Nutrient-rich bee pollen: a treasure trove of active natural metabolites, J. Funct.Foods 49 (2018) 472–484, https://doi.org/10.1016/j.jff.2018.09.008.
[20] S.K.T. Seraglio, M. Schulz, P. Brugnerotto, B. Silva, L.V. Gonzaga, R. Fett, A.C.O. Costa, Quality, composition and health-protective properties of citrus honey: a review, Food Res. Int. 143 (2021) 110268, https://doi.org/10.1016/j.foodres.2021.110268.
[21] M. Woźniak, L. Mrówczyńska, A. Waśkiewicz, T. Rogoziński, I. Ratajczak, The role of seasonality on the chemical composition, antioxidant activity and cytotoxicity of Polish propolis in human erythrocytes, Revista Brasileira de Farmacognosia 29 (2019) 301–308, https://doi.org/10.1016/j.bjp.2019.02.002.
[22] S. Almasaudi, The antibacterial activities of honey, Saudi J. Biol. Sci. 28 (2021) 2188–2196, https://doi.org/10.1016/j.sjbs.2020.10.017.
[23] N.E. Bayram, Y.C. Gercek, S. Çelik, N. Mayda, A.Ž. Kostić, A.M. Dramićanin, A. Özkök, Phenolic and free amino acid profiles of bee bread and bee pollen with the same botanical origin – similarities and differences, Arab. J. Chem. 14 (2021) 103004, https://doi.org/10.1016/j.arabjc.2021.103004.
[24] K. Pant, A. Sharma, H.K. Chopra, V. Nanda, Impact of biodiversification on propolis composition, functionality, and application in foods as natural preservative: a review, Food Control 155 (2024) 110097, https://doi.org/10.1016/j.foodcont.2023.110097.
[25] D.A. Tafere, Chemical composition and uses of honey: a review, Journal of Food Science and Nutrition Research 4 (2021) 194–201.

[26] H. Zhang, Q. Lu, R. Liu, Widely targeted metabolomics analysis reveals the effect of fermentation on the chemical composition of bee pollen, Food Chem. 375 (2022) 131908, https://doi.org/10.1016/j.foodchem.2021.131908.
[27] X.-H. Zhang, H.-W. Gu, R.-J. Liu, X.-D. Qing, J.-F. Nie, A comprehensive review of the current trends and recent advancements on the authenticity of honey, Food Chem. X 19 (2023) 100850, https://doi.org/10.1016/j.fochx.2023.100850.
[28] V. Aylanc, S.I. Falcão, M. Vilas-Boas, Bee pollen and bee bread nutritional potential: chemical composition and macronutrient digestibility under in vitro gastrointestinal system, Food Chem. 413 (2023) 135597, https://doi.org/10.1016/j.foodchem.2023.135597.
[29] M.A. Calegari, A. Prasniewski, C.D. Silva, R.Y. Sado, F.M.C. Maia, L.M.S. Tonial, T.L.C. Oldoni, Propolis from Southwest of Parana produced by selected bees: influence of seasonality and food supplementation on antioxidant activity and phenolic profile, An. Acad. Bras. Ciênc. 89 (2017) 45–55, https://doi.org/10.1590/0001-3765201620160499.
[30] M. Carocho, I.C.F.R. Ferreira, A review on antioxidants, prooxidants and related controversy: natural and synthetic compounds, screening and analysis methodologies and future perspectives, Food Chem. Toxicol. 51 (2013) 15–25, https://doi.org/10.1016/j.fct.2012.09.021.
[31] F.M. de A. de Carvalho, J.K. Schneider, C.V.F. de Jesus, L.N. de Andrade, R.G. Amaral, J.M. David, L.C. Krause, P. Severino, C.M.F. Soares, E. Caramão Bastos, F.F. Padilha, S.V.F. Gomes, R. Capasso, A. Santini, E.B. Souto, R.L.C. de Albuquerque-Júnior, Brazilian red propolis: extracts production, physicochemical characterization, and cytotoxicity profile for antitumor activity, Biomolecules 10 (2020) 726, https://doi.org/10.3390/biom10050726.
[32] H. Laaroussi, P. Ferreira-Santos, Z. Genisheva, M. Bakour, D. Ousaaid, J.A. Teixeira, B. Lyoussi, Unraveling the chemical composition, antioxidant, α-amylase and α-glucosidase inhibition of Moroccan propolis, Food Biosci. 42 (2021) 101160, https://doi.org/10.1016/j.fbio.2021.101160.
[33] E.I. Santacruz, J.M. Benavidez, H.J. Gámez, Identificación de flora y analisis nutricional de miel de abeja para la produccion apicola, Biotecnología en el Sector Agropecuario y Agroindustrial 14 (2016) 37–44, https://doi.org/10.18684/BSAA(14)37-44.
[34] N. Böke Sarıkahya, A.C. Gören, G. Sümer Okkalı, F.O. Çöven, B. Orman, D. Kırcı, B. Yücel, D. Kışla, B. Demirci, M. Altun, A.N. Önem, A. Nalbantsoy, Chemical composition and biological activities of propolis samples from different geographical regions of Turkey, Phytochem. Lett. 44 (2021) 129–136, https://doi.org/10.1016/j.phytol.2021.06.008.
[35] T.M. Kegode, J.L. Bargul, H.O. Mokaya, H.M.G. Lattorff, Phytochemical Composition and Bio-Functional Properties of Apis mellifera Propolis from Kenya, vol. 9, Royal Society Open Science, 2022 211214, https://doi.org/10.1098/rsos.211214.
[36] M. Popova, B. Trusheva, V. Bankova, Propolis of stingless bees: a phytochemist's guide through the jungle of tropical biodiversity, Phytomedicine 86 (2021) 153098, https://doi.org/10.1016/j.phymed.2019.153098.
[37] A.C. Urcan, A.D. Criste, D.S. Dezmirean, R. Mărgăoan, A. Caeiro, M. Graça Campos, Similarity of data from bee bread with the same taxa collected in India and Romania, Molecules 23 (2018) 2491, https://doi.org/10.3390/molecules23102491.
[38] M. Gao, J. Lan, B. Bao, W. Yao, Y. Cao, M. Shan, F. Cheng, P. Chen, L. Zhang, Effects of carbonized process on quality control, chemical composition and pharmacology of Typhae Pollen: a review, J. Ethnopharmacol. 270 (2021) 113774, https://doi.org/10.1016/j.jep.2020.113774.
[39] Z.B. Ghorghi, S. Yeganehzad, M.A. Hesarinejad, A. Faezian, V. Kutsenkova, Z. Gao, K. Nishinari, N. Nepovinnykh, Fabrication of novel hybrid gel based on beeswax oleogel: application in the compound chocolate formulation, Food Hydrocolloids 140 (2023) 108599, https://doi.org/10.1016/j.foodhyd.2023.108599.
[40] F. Giampieri, J.L. Quiles, D. Cianciosi, T.Y. Forbes-Hernández, F.J. Orantes-Bermejo, J.M. Alvarez-Suarez, M. Battino, Bee products: an emblematic example of underutilized sources of bioactive compounds, J. Agric. Food Chem. 70 (2022) 6833–6848, https://doi.org/10.1021/acs.jafc.1c05822.
[41] L. Svečnjak, O. Jović, S. Prđun, J. Rogina, Z. Marijanović, J. Car, M. Matošević, I. Jerković, Influence of beeswax adulteration with paraffin on the composition and quality of honey determined by physico-chemical analyses, 1H NMR, FTIR-ATR and HS-SPME/GC–MS, Food Chem. 291 (2019) 187–198, https://doi.org/10.1016/j.foodchem.2019.03.151.
[42] R. Végh, M. Csóka, Z. Mednyánszky, L. Sipos, Potentially toxic trace elements in bee bread, propolis, beeswax and royal jelly – a review of the literature and dietary risk assessment, Chemosphere 339 (2023) 139571, https://doi.org/10.1016/j.chemosphere.2023.139571.
[43] T.A. Azeez, P. Chimah, A.F. Hassan, A. Moradeyo, U. Umoren, E. Eguzozie, Dietary recommendation in diabetes care: carbohydrate counting and caloric content of Nigerian foods, International Journal of Noncommunicable Diseases 5 (2020) 201, https://doi.org/10.4103/jncd.jncd_64_20.
[44] N.H. Low, P. Sporns, Analysis and quantitation of minor di- and trisaccharides in honey, using capillary gas chromatography, J. Food Sci. 53 (1988) 558–561, https://doi.org/10.1111/j.1365-2621.1988.tb07755.x.
[45] D.H. Chilán-Quimís, G. Molina-Toala, V. Saltos-Buri, J. Moran-Zavala, Analisis socio – economico de los productores de miel de abeja en el sitio Quimis, despues del desastre natural 16[a], Polo del Conocimiento 4 (2019) 61–77, https://doi.org/10.23857/pc.v4i3.917.
[46] W.S. Ayoub, Ritu, I. Zahoor, A.H. Dar, S. Farooq, T.A. Mir, T.A. Ganaie, S. Srivastava, V.K. Pandey, A. Altaf, Exploiting the polyphenolic potential of honey in the prevention of chronic diseases, Food Chemistry Advances 3 (2023) 100373, https://doi.org/10.1016/j.focha.2023.100373.
[47] T.L. Mesele, Review on physico-chemical properties of honey in Eastern Africa, J. Apicult. Res. 60 (2021) 33–45, https://doi.org/10.1080/00218839.2020.1754566.
[48] J.S.P. Varela, P.M.E. Carriel, Análisis de la cristalización de la miel de abeja como indicativo de su pureza: Analysis of the bee honey crystallization as an indication of its purity, Kalpana- Revista de Investigación, 2022, pp. 92–106.
[49] T.C. Pereira, A.G. Cruz, J.T. Guimarães, G. Cravotto, E.M.M. Flores, Ultrasonication for honey processing and preservation: a brief overview, Food Res. Int. 174 (2023) 113579, https://doi.org/10.1016/j.foodres.2023.113579.
[50] E.J.S. Llorente, H.J.A. Álvarez, J.M.C. Cano, B.M.S. Arias, S.A.P. Lascano, Evaluación del contenido de hidroximetilfurfural en miel comercial y artesanal de Los Ríos-Babahoyo, Journal of Science and Research 8 (2023) 57–79.
[51] F. Abdellah, C. Makhloufi, L. Boukraa, S.M. Hammoudi, A. Safa, N. Dellel, A. Benamara, M. Benhadiri, N. Marouf, R. Benaraba, Physico-chemical properties and antibacterial and antioxidant activity of two varieties of honey from Algerian steppe, J.Apit.Nat. 3 (2020) 59–74, https://doi.org/10.35206/jan.774052.
[52] D. Sgargi, B. Adam, L.T. Budnik, G. Dinelli, H.R. Moldovan, M.J. Perry, P.T.J. Scheepers, V. Schlünssen, J.P. Teixeira, D. Mandrioli, F. Belpoggi, Protocol for a systematic review and meta-analysis of human exposure to pesticide residues in honey and other bees' products, Environ. Res. 186 (2020) 109470, https://doi.org/10.1016/j.envres.2020.109470.
[53] S.A. Martínez, D.P. Vega, J.R.L. Gutiérrez, A.L.S. Yáñez, N.W. de Torres, N.C. Rocha, Análisis del perfil de aminoácidos de mieles de México por CLAR/F como estrategia para la determinación del origen geográfico, Investigación y Desarrollo en Ciencia y Tecnología de Alimentos. 8 (2023) 841–850, https://doi.org/10.29105/idcyta.v8i1.108.
[54] C. Mutlu, S.A. Tontul, M. Erbaş, Production of a minimally processed jelly candy for children using honey instead of sugar, LWT 93 (2018) 499–505, https://doi.org/10.1016/j.lwt.2018.03.064.
[55] C.D. Dumitru, I.A. Neacsu, A.M. Grumezescu, E. Andronescu, Bee-Derived products: chemical composition and applications in skin tissue engineering, Pharmaceutics 14 (2022) 750, https://doi.org/10.3390/pharmaceutics14040750.
[56] D. Cianciosi, T.Y. Forbes-Hernández, S. Afrin, M. Gasparrini, P. Reboredo-Rodriguez, P.P. Manna, J. Zhang, L. Bravo Lamas, S. Martínez Flórez, P. Agudo Toyos, J.L. Quiles, F. Giampieri, M. Battino, Phenolic compounds in honey and their associated health benefits: a review, Molecules 23 (2018) 2322, https://doi.org/10.3390/molecules23092322.
[57] A.J. Siddiqui, S.G. Musharraf, M.I. Choudhary, A. Rahman, Application of analytical methods in authentication and adulteration of honey, Food Chem. 217 (2017) 687–698, https://doi.org/10.1016/j.foodchem.2016.09.001.
[58] T. De Beer, M. Otto, B. Pretoruis, H.C. Schönfeldt, Monitoring the quality of honey: South African case study, Food Chem. 343 (2021) 128527, https://doi.org/10.1016/j.foodchem.2020.128527.
[59] H. Bayir, A. Aygun, Heavy metal in honey bees, honey, and pollen produced in rural and urban areas of Konya province in Turkey, Environ. Sci. Pollut. Res. 29 (2022) 74569, https://doi.org/10.1007/s11356-022-21017-z. –74578.
[60] W. Yohannes, B. Singh Chandravanshi, G. Moges, Assessment of trace metals and physicochemical parameters of commercially available honey in Ethiopia, Chem. Int. 4 (2022) 91–101.

[61] D. Tibebe, M. Hussen, M. Mulugeta, D. yenealem, Z. Moges, M. Gedefaw, Y. Kassa, Assessment of selected heavy metals in honey samples using flame atomic absorption spectroscopy (FAAS), Ethiopia, BMC Chem 16 (2022) 87, https://doi.org/10.1186/s13065-022-00878-y.
[62] N. Abd Rashid, S.N.F. Mohammed, S.A. Syed Abd Halim, N.A. Ghafar, N.A. Abdul Jalil, Therapeutic potential of honey and propolis on ocular disease, Pharmaceuticals 15 (2022) 1419, https://doi.org/10.3390/ph15111419.
[63] S. El-Guendouz, B. Lyoussi, M.G. Miguel, Insight on propolis from mediterranean countries: chemical composition, biological activities and application fields, Chem. Biodivers. 16 (2019) e1900094, https://doi.org/10.1002/cbdv.201900094.
[64] Y. Irigoiti, A. Navarro, D. Yamul, C. Libonatti, A. Tabera, M. Basualdo, The use of propolis as a functional food ingredient: a review, Trends Food Sci. Technol. 115 (2021) 297–306, https://doi.org/10.1016/j.tifs.2021.06.041.
[65] D. Katiyar, Propolis: a natural biomaterial, Mater. Today: Proc. (2023), https://doi.org/10.1016/j.matpr.2023.05.522.
[66] R. Cauich-Kumul, M.R. Segura Campos, Chapter 12 - bee propolis: properties, chemical composition, applications, and potential health effects, in: M.R. S. Campos (Ed.), Bioactive Compounds, Woodhead Publishing, 2019, pp. 227–243, https://doi.org/10.1016/B978-0-12-814774-0.00012-8.
[67] Y. Irigoiti, D.K. Yamul, A.S. Navarro, Co-crystallized sucrose with propolis extract as a food ingredient: powder characterization and antioxidant stability, LWT 143 (2021) 111164, https://doi.org/10.1016/j.lwt.2021.111164.
[68] H.A.V. Cáceda, L.A.C. Ganoza, Evaluación del efecto antibacteriano sinérgico de rifamicina en propóleo sobre bacterias grampositivas, Rev. Cubana Med. Mil. 50 (2021). https://www.medigraphic.com/cgi-bin/new/resumen.cgi?IDARTICULO=110120. (Accessed 26 August 2023).
[69] J.C. Vázquez, Caracterización botánica de los propóleos producidos en distinto orígen geográfico en la región apícola I - Cuenca del Salado, Pcia. de Buenos Aires, Tesis doctoral, Universitat Politècnica de València, 2011, https://doi.org/10.4995/Thesis/10251/12264.
[70] M. Bucekova, V. Bugarova, J. Godocikova, J. Majtan, Demanding new honey qualitative standard based on antibacterial activity, Foods 9 (2020) 1263, https://doi.org/10.3390/foods9091263.
[71] Engin Gündoğdu, Songül Çakmakçi, IHsan Güngör Şat, An overview of honey: its composition, nutritional and functional properties, JFSE 9 (2019), https://doi.org/10.17265/2159-5828/2019.01.003.
[72] S. Bouchelaghem, Propolis characterization and antimicrobial activities against Staphylococcus aureus and Candida albicans: a review, Saudi J. Biol. Sci. 29 (2022) 1936–1946, https://doi.org/10.1016/j.sjbs.2021.11.063.
[73] K. Pant, M. Thakur, H.K. Chopra, V. Nanda, M. Javed Ansari, G. Pietramellara, S.I. Pathan, S.A. Alharbi, H.S. Almoallim, R. Datta, Characterization and discrimination of Indian propolis based on physico-chemical, techno-functional, thermal and textural properties: a multivariate approach, J. King Saud Univ. Sci. 33 (2021) 101405, https://doi.org/10.1016/j.jksus.2021.101405.
[74] M.G. Shehata, F.T. Ahmad, A.N. Badr, S.H. Masry, S.A. El-Sohaimy, Chemical analysis, antioxidant, cytotoxic and antimicrobial properties of propolis from different geographic regions, Ann. Agric. Sci. (Cairo) 65 (2020) 209–217, https://doi.org/10.1016/j.aoas.2020.12.001.
[75] O. Anjos, N. Seixas, C.A.L. Antunes, M.G. Campos, V. Paula, L.M. Estevinho, Quality of bee pollen submitted to drying, pasteurization, and high-pressure processing – a comparative approach, Food Res. Int. 170 (2023) 112964, https://doi.org/10.1016/j.foodres.2023.112964.
[76] T. Kolipaka, P. Khairnar, V. Phatale, G. Pandey, P. Famta, S. Shah, A. Asthana, S. Nanduri, R.S. Raghuvanshi, S. Srivastava, Multifaceted roles of pollen in the management of cancer, Int. J. Pharm. 643 (2023) 123278, https://doi.org/10.1016/j.ijpharm.2023.123278.
[77] A.M.G. Darwish, A.A. Abd El-Wahed, M.G. Shehata, H.R. El-Seedi, S.H.D. Masry, S.A.M. Khalifa, H.M. Mahfouz, S.A. El-Sohaimy, Chemical profiling and nutritional evaluation of bee pollen, bee bread, and royal jelly and their role in functional fermented dairy products, Molecules 28 (2023) 227, https://doi.org/10.3390/molecules28010227.
[78] M. Campos, C. Frigerio, J. Lopes, S. Bogdanov, What is the future of Bee-Pollen? J. ApiProduct ApiMed. Sci. 2 (2010) 131–144, https://doi.org/10.3896/IBRA.4.02.4.01.
[79] M. Thakur, V. Nanda, Composition and functionality of bee pollen: a review, Trends Food Sci. Technol. 98 (2020) 82–106, https://doi.org/10.1016/j.tifs.2020.02.001.
[80] S.A.M. Khalifa, M.H. Elashal, N. Yosri, M. Du, S.G. Musharraf, L. Nahar, S.D. Sarker, Z. Guo, W. Cao, X. Zou, A.A. Abd El-Wahed, J. Xiao, H.A. Omar, M.-E. F. Hegazy, H.R. El-Seedi, Bee pollen: current status and therapeutic potential, Nutrients 13 (2021) 1876, https://doi.org/10.3390/nu13061876.
[81] C.M. Zuluaga-Dominguez, C.A. Fuenmayor, Chapter 13 - bee bread and gut microbiota, in: D. Boyacioglu (Ed.), Bee Products and Their Applications in the Food and Pharmaceutical Industries, Academic Press, 2022, pp. 315–345, https://doi.org/10.1016/B978-0-323-85400-9.00010-1.
[82] R. Mărgăoan, A. Özkök, Ş. Keskin, N. Mayda, A.C. Urcan, M. Cornea-Cipcigan, Bee collected pollen as a value-added product rich in bioactive compounds and unsaturated fatty acids: a comparative study from Turkey and Romania, LWT 149 (2021) 111925, https://doi.org/10.1016/j.lwt.2021.111925.
[83] Y. Frolova, V. Sarkisyan, R. Sobolev, M. Makarenko, M. Semin, A. Kochetkova, The influence of edible oils' composition on the properties of beeswax-based oleogels, Gels 8 (2022) 48, https://doi.org/10.3390/gels8010048.
[84] L. Svečnjak, L.A. Chesson, A. Gallina, M. Maia, M. Martinello, F. Mutinelli, M.N. Muz, F.M. Nunes, F. Saucy, B.J. Tipple, K. Wallner, E. Waś, T.A. Waters, Standard methods for Apis mellifera beeswax research, J. Apicult. Res. 58 (2019) 1–108, https://doi.org/10.1080/00218839.2019.1571556.
[85] G. Fayaz, S.A.H. Goli, M. Kadivar, F. Valoppi, L. Barba, S. Calligaris, M.C. Nicoli, Potential application of pomegranate seed oil oleogels based on monoglycerides, beeswax and propolis wax as partial substitutes of palm oil in functional chocolate spread, LWT 86 (2017) 523–529, https://doi.org/10.1016/j.lwt.2017.08.036.
[86] B.M. Al-Shehri, T. Haddadi, E.M. Alasmari, H.A. Ghramh, K.A. Khan, M.E.A. Mohammed, M. Sager Alotaibi, M.A.A. El-Niweiri, A. Hamdi Assiri, M.M. Khayyat, Effect of storage time and floral origin on the physicochemical properties of beeswax and the possibility of using it as a phase changing material in the thermal storage energy technology, Foods 11 (2022) 3920, https://doi.org/10.3390/foods11233920.
[87] G. Gupta, K. Anjali, Environmentally friendly beeswax: properties, composition, adulteration, and its therapeutic benefits, IOP Conf. Ser. Earth Environ. Sci. 1110 (2023) 012041, https://doi.org/10.1088/1755-1315/1110/1/012041.
[88] S.-K. Kim, S.-M. Han, S.-G. Kim, H.-Y. Kim, H.-M. Choi, H.-J. Lee, H.-J. Moon, S.O. Woo, Analysis of the physicochemical properties of beeswax of Apis mellifera linnaeus and Apis cerana fabricius, Apiculture 37 (2022) 393–396, https://doi.org/10.17519/apiculture.2022.11.37.4.393.
[89] N. da Silva Santana, C.G. Mothé, M. Nele de Souza, M.G. Mothé, Thermal and rheological study of artificial and natural powder tabletop sweeteners, Food Res. Int. 162 (2022) 112039, https://doi.org/10.1016/j.foodres.2022.112039.
[90] D.K. Mahato, R. Keast, D.G. Liem, C.G. Russell, S. Cicerale, S. Gamlath, Optimisation of natural sweeteners for sugar reduction in chocolate flavoured milk and their impact on sensory attributes, Int. Dairy J. 115 (2021) 104922, https://doi.org/10.1016/j.idairyj.2020.104922.
[91] R.D. Mattes, S.-Y. Tan, R.M. Tucker, Sweeteners: sensory properties, digestion, consumption trends, and health effects, in: B. Caballero (Ed.), Encyclopedia of Human Nutrition, fourth ed., Academic Press, Oxford, 2023, pp. 624–638, https://doi.org/10.1016/B978-0-12-821848-8.00014-7.
[92] C.J. Pilco, R.M. Quicaliquin, B.A. Viscarra, E.S. Meneces, H.S. Salguero, Edulcorantes no calóricos en la industria alimentaria: efectos y beneficios frente a la salud humana: non-caloric sweeteners in the food industry: effects and benefits on human health, LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades 4 (2023) 1692–1700, https://doi.org/10.56712/latam.v4i1.370.
[93] X. Zhu, S. Li, Y. Shan, Z. Zhang, G. Li, D. Su, F. Liu, Detection of adulterants such as sweeteners materials in honey using near-infrared spectroscopy and chemometrics, J. Food Eng. 101 (2010) 92–97, https://doi.org/10.1016/j.jfoodeng.2010.06.014.
[94] A.M. Ares, S. Valverde, J.L. Bernal, M.J. Nozal, J. Bernal, Extraction and determination of bioactive compounds from bee pollen, J. Pharmaceut. Biomed. Anal. 147 (2018) 110–124, https://doi.org/10.1016/j.jpba.2017.08.009.
[95] F. Guo, Y. Yang, Y. Duan, C. Li, H. Gao, H. Liu, Q. Cui, Z. Guo, X. Liu, Z. Wang, Quality marker discovery and quality evaluation of eucommia ulmoides pollen using UPLC-QTOF-MS combined with a DPPH-HPLC antioxidant activity screening method, Molecules 28 (2023) 5288, https://doi.org/10.3390/molecules28135288.
[96] M. Krystyjan, D. Gumul, R. Ziobro, A. Korus, The fortification of biscuits with bee pollen and its effect on physicochemical and antioxidant properties in biscuits, LWT - Food Sci. Technol. (Lebensmittel-Wissenschaft -Technol.) 63 (2015) 640–646, https://doi.org/10.1016/j.lwt.2015.03.075.

[97] O. Sokmen, S. Ozdemir, A.N. Dundar, A. Cinar, Quality properties and bioactive compounds of reduced-fat cookies with bee pollen, Int. J. Gastron. Food Sci. 29 (2022) 100557, https://doi.org/10.1016/j.ijgfs.2022.100557.
[98] R. Yildiz, M. Maskan, Optimization of a green tea beverage enriched with honey and bee pollen, Int. J. Gastron. Food Sci. 30 (2022) 100597, https://doi.org/10.1016/j.ijgfs.2022.100597.
[99] X. Zhang, M. Yu, X. Zhu, R. Liu, Q. Lu, Metabolomics reveals that phenolamides are the main chemical components contributing to the anti-tyrosinase activity of bee pollen, Food Chem. 389 (2022) 133071, https://doi.org/10.1016/j.foodchem.2022.133071.
[100] M. Ayoob, A.H. Shah, Z.A. Nizamani, M.F. Ayoob, D.K. Bhuptani, A.S. Baloch, Antimicrobial and antioxidative effects of honey marination on beef meat, PJZ 55 (2023), https://doi.org/10.17582/journal.pjz/20211203051239.
[101] K. Sarabandi, Z. Akbarbaglu, N. Mazloomi, P. Gharehbeglou, S.H. Peighambardoust, S.M. Jafari, Structural modification of poppy-pollen protein as a natural antioxidant, emulsifier and carrier in spray-drying of O/W-emulsion: physicochemical and oxidative stabilization, Int. J. Biol. Macromol. (2023) 126260, https://doi.org/10.1016/j.ijbiomac.2023.126260.
[102] K. Sarabandi, Z. Akbarbaglu, S.H. Peighambardoust, A. Ayaseh, S.M. Jafari, Biological stabilization of natural pigment-phytochemical from poppy-pollen (Papaver bracteatum) extract: functional food formulation, Food Chem. 429 (2023) 136885, https://doi.org/10.1016/j.foodchem.2023.136885.
[103] A. Ezazi, A. Javadi, H. Jafarizadeh-Malmiri, H. Mirzaei, Development of a chitosan-propolis extract edible coating formulation based on physico-chemical attributes of hens' eggs: optimization and characteristics edible coating of egg using chitosan and propolis, Food Biosci. 40 (2021) 100894, https://doi.org/10.1016/j.fbio.2021.100894.
[104] E. Kuley, M.M. Kuscu, M. Durmus, Y. Ucar, Inhibitory activity of Co-microencapsulation of cell free supernatant from Lactobacillus plantarum with propolis extracts towards fish spoilage bacteria, LWT 146 (2021) 111433, https://doi.org/10.1016/j.lwt.2021.111433.
[105] J.F. Mafra, T.S. de Santana, A.I.C. Cruz, M.A. Ferreira, F.M. Miranda, F.M. Araújo, P.R. Ribeiro, N.S. Evangelista-Barreto, Influence of red propolis on the physicochemical, microbiological and sensory characteristics of tilapia (Oreochromis niloticus) salami, Food Chem. 394 (2022) 133502, https://doi.org/10.1016/j.foodchem.2022.133502.
[106] A. Vasilaki, M. Hatzikamari, A. Stagkos-Georgiadis, A.M. Goula, I. Mourtzinos, A natural approach in food preservation: propolis extract as sorbate alternative in non-carbonated beverage, Food Chem. 298 (2019) 125080, https://doi.org/10.1016/j.foodchem.2019.125080.
[107] I. Villacrés-Granda, D. Coello, A. Proaño, I. Ballesteros, D.W. Roubik, G. Jijón, G. Granda-Albuja, S. Granda-Albuja, R. Abreu-Naranjo, F. Maza, E. Tejera, A. M. González-Paramás, P. Bullón, J.M. Alvarez-Suarez, Honey quality parameters, chemical composition and antimicrobial activity in twelve Ecuadorian stingless bees (Apidae: apinae: Meliponini) tested against multiresistant human pathogens, LWT 140 (2021) 110737, https://doi.org/10.1016/j.lwt.2020.110737.
[108] A. Borriello, N. Antonella Miele, P. Masi, A. Aiello, S. Cavella, Effect of fatty acid composition of vegetable oils on crystallization and gelation kinetics of oleogels based on natural wax, Food Chem. 375 (2022) 131805, https://doi.org/10.1016/j.foodchem.2021.131805.
[109] A. Habibi, C. Dekiwadia, S. Kasapis, T. Truong, Fabrication of double emulsion gel using monoacylglycerol and whey protein concentrate: the effects of primary emulsion gel fraction and particle size, J. Food Eng. 341 (2023) 111350, https://doi.org/10.1016/j.jfoodeng.2022.111350.
[110] Z. Huang, B. Guo, D. Gong, G. Zhang, Oleogel-structured emulsions: a review of formation, physicochemical properties and applications, Food Chem. 404 (2023) 134553, https://doi.org/10.1016/j.foodchem.2022.134553.
[111] L. Li, G. Liu, Y. Lin, Physical and bloom stability of low-saturation chocolates with oleogels based on different gelation mechanisms, LWT 140 (2021) 110807, https://doi.org/10.1016/j.lwt.2020.110807.
[112] S. Manzoor, F.A. Masoodi, R. Rashid, F. Naqash, M. Ahmad, Oleogels for the development of healthy meat products: a review, Applied Food Research 2 (2022) 100212, https://doi.org/10.1016/j.afres.2022.100212.
[113] B.M. Trinh, M. Smith, T.H. Mekonnen, A nanomaterial-stabilized starch-beeswax Pickering emulsion coating to extend produce shelf-life, Chem. Eng. J. 431 (2022) 133905, https://doi.org/10.1016/j.cej.2021.133905.
[114] S. Ali, M.A. Anjum, S. Ejaz, S. Hussain, S. Ercisli, M.S. Saleem, H. Sardar, Carboxymethyl cellulose coating delays chilling injury development and maintains eating quality of 'Kinnow' Mandarin fruits during low temperature storage, Int. J. Biol. Macromol. 168 (2021) 77–85, https://doi.org/10.1016/j.ijbiomac.2020.12.028.
[115] L. Cruz-Ortiz, K. Escobar-Ventura, M. Flores-Méndez, M.E. Urbina-Reyes, A. Vázquez-Ovando, Recubrimientos con cera de abeja, extractos de ajo y sauce para aumentar la vida postcosecha del banano Gran Enano, Informador Técnico. 85 (2021) 172–183, https://doi.org/10.23850/22565035.3685.
[116] A.S. Formiga, J.S. Pinsetta, E.M. Pereira, I.N.F. Cordeiro, B.-H. Mattiuz, Use of edible coatings based on hydroxypropyl methylcellulose and beeswax in the conservation of red guava 'Pedro Sato, Food Chem. 290 (2019) 144–151, https://doi.org/10.1016/j.foodchem.2019.03.142.
[117] S.F. Hosseini, Z. Mousavi, D.J. McClements, Beeswax: a review on the recent progress in the development of superhydrophobic films/coatings and their applications in fruits preservation, Food Chem. 424 (2023) 136404, https://doi.org/10.1016/j.foodchem.2023.136404.
[118] G. Li, X. Li, J. Li, Z. Lv, H. Wang, R. Gao, L. Luo, Effect of natural green coating materials on the postharvest quality of Prunus salicina Lindl. cv. 'Shazikongxinli fruit': a sustainable approach to prevent economic and food loss, Sustainable Chemistry and Pharmacy 24 (2021) 100516, https://doi.org/10.1016/j.scp.2021.100516.
[119] V. Patel, B. Boruff, E. Biggs, N. Pauli, Assessing the influence of variation in forage availability on spatial patterns of beehive migration using a hybrid modelling approach – B-Agent, Appl. Geogr. 157 (2023) 103003, https://doi.org/10.1016/j.apgeog.2023.103003.
[120] A. Sinha, P.P.S. Gill, S.K. Jawandha, P. Kaur, S.K. Grewal, Salicylic acid enriched beeswax coatings suppress fruit softening in pears by modulation of cell wall degrading enzymes under different storage conditions, Food Packag. Shelf Life 32 (2022) 100821, https://doi.org/10.1016/j.fpsl.2022.100821.
[121] F.F. Sousa, J.S. Pinsetta Junior, K.T.E.F. Oliveira, E.C.N. Rodrigues, J.P. Andrade, B.-H. Mattiuz, Conservation of 'Palmer' mango with an edible coating of hydroxypropyl methylcellulose and beeswax, Food Chem. 346 (2021) 128925, https://doi.org/10.1016/j.foodchem.2020.128925.
[122] R. Zhang, X. Zhai, W. Wang, H. Hou, Preparation and evaluation of agar/maltodextrin-beeswax emulsion films with various hydrophilic-lipophilic balance emulsifiers, Food Chem. 384 (2022) 132541, https://doi.org/10.1016/j.foodchem.2022.132541.
[123] A.K. Alkhaldi, H. Alshiddi, M. Aljubair, S. Alzahrani, A. Alkhaldi, K.S. Al-khalifa, B. Gaffar, Sex differences in oral health and the consumption of sugary diets in a Saudi Arabian population, Patient Prefer. Adherence 15 (2021) 1121–1131, https://doi.org/10.2147/PPA.S308008.
[124] L.E. Wagenknecht, J.M. Lawrence, S. Isom, E.T. Jensen, D. Dabelea, A.D. Liese, L.M. Dolan, A.S. Shah, A. Bellatorre, K. Sauder, S. Marcovina, K. Reynolds, C. Pihoker, G. Imperatore, J. Divers, Trends in incidence of youth-onset type 1 and type 2 diabetes in the USA, 2002–18: results from the population-based SEARCH for Diabetes in Youth study, Lancet Diabetes Endocrinol. 11 (2023) 242–250, https://doi.org/10.1016/S2213-8587(23)00025-6.
[125] H. Wu, C.C. Patterson, X. Zhang, R.B.A. Ghani, D.J. Magliano, E.J. Boyko, G.D. Ogle, A.O.Y. Luk, Worldwide estimates of incidence of type 2 diabetes in children and adolescents in 2021, Diabetes Res. Clin. Pract. 185 (2022) 109785, https://doi.org/10.1016/j.diabres.2022.109785.
[126] R. Di Monaco, N.A. Miele, E.K. Cabisidan, S. Cavella, Strategies to reduce sugars in food, Curr. Opin. Food Sci. 19 (2018) 92–97, https://doi.org/10.1016/j.cofs.2018.03.008.
[127] B. Covaci, R. Brejea, M. Covaci, Sweeteners world trade and behaviour in the pandemic. Evidence from honey remedies nexus mountain Apis mellifera product, Sugar Tech 25 (2023) 938–949, https://doi.org/10.1007/s12355-023-01243-6.
[128] J.P. Deneesha Madunimani, B. Perumpuli, K.N.N. Silva, Development of a Ready to Drink Cinnamon-Based Beverage Using Bee Honey as a Natural Sweetener, 2022. http://ir.lib.ruh.ac.lk/xmlui/handle/iruor/5598. (Accessed 20 November 2023).
[129] M. Donders, B. Labra, J. Chávez, J. Tapia-Merino, O. Muñoz, Spray-Dried honey powder as a sweetener: sensory characterization, Bee World 98 (2021) 136–141, https://doi.org/10.1080/0005772X.2021.1892998.
[130] I. Kowalczuk, J. Gębski, D. Stangierska, A. Szymańska, Determinants of honey and other bee products use for culinary, cosmetic, and medical purposes, Nutrients 15 (2023) 737, https://doi.org/10.3390/nu15030737.

[131] G. Papa, R. Maier, A. Durazzo, M. Lucarini, I.K. Karabagias, M. Plutino, E. Bianchetto, R. Aromolo, G. Pignatti, A. Ambrogio, M. Pellecchia, I. Negri, The honey bee Apis mellifera: an insect at the interface between human and ecosystem health, Biology 11 (2022) 233, https://doi.org/10.3390/biology11020233.
[132] R. Testa, A. Asciuto, G. Schifani, E. Schimmenti, G. Migliore, Quality determinants and effect of therapeutic properties in honey consumption. An exploratory study on Italian consumers, Agriculture 9 (2019) 174, https://doi.org/10.3390/agriculture9080174.
[133] A. Proaño, D. Coello, I. Villacrés-Granda, I. Ballesteros, A. Debut, K. Vizuete, A. Brenciani, J.M. Álvarez-Suarez, The osmotic action of sugar combined with hydrogen peroxide and bee-derived antibacterial peptide Defensin-1 is crucial for the antibiofilm activity of eucalyptus honey, LWT 136 (2021) 110379, https://doi.org/10.1016/j.lwt.2020.110379.
[134] C.L. López-Patiño, C. Arroqui, S. Horvitz, P. Vírseda, Strategies to enhance propolis ethanolic extract's flavor for its use as a natural preservative in beef, Current Research in Nutrition and Food Science Journal 9 (2021) 521–532.
[135] M.S. Almuhayawi, Propolis as a novel antibacterial agent, Saudi J. Biol. Sci. 27 (2020) 3079–3086, https://doi.org/10.1016/j.sjbs.2020.09.016.
[136] I. Przybyłek, T.M. Karpiński, Antibacterial properties of propolis, Molecules 24 (2019) 2047, https://doi.org/10.3390/molecules24112047.
[137] İ. Kahramanoğlu, V. Okatan, C. Wan, Biochemical composition of propolis and its efficacy in maintaining postharvest storability of fresh fruits and vegetables, J. Food Qual. 2020 (2020) e8869624, https://doi.org/10.1155/2020/8869624.
[138] F. Infante-Rodríguez, Y. Bautista-Martínez, B. Reyes-Cabrera, L.D. Granados-Rivera, J. Efrén-Ramírez Bribiesca, M. Ruiz-Albarrán, J. Salinas-Chavira, Use of propolis as a supplement in the diet of broiler chickens to increase shelf-life of breast muscle, CyTA - J. Food 18 (2020) 728–733, https://doi.org/10.1080/19476337.2020.1840445.
[139] Y. Pu, H. Jiang, Y. Zhang, J. Cao, W. Jiang, Advances in propolis and propolis functionalized coatings and films for fruits and vegetables preservation, Food Chem. 414 (2023) 135662, https://doi.org/10.1016/j.foodchem.2023.135662.
[140] M. Mahdavi-Roshan, S. Gheibi, A. Pourfarzad, Effect of propolis extract as a natural preservative on quality and shelf life of marinated chicken breast (chicken Kebab), LWT 155 (2022) 112942, https://doi.org/10.1016/j.lwt.2021.112942.
[141] N.A. Abdullah, F. Ja'afar, H.M. Yasin, H. Taha, M.I.R. Petalcorin, M.H. Mamit, E. Kusrini, A. Usman, Physicochemical analyses, antioxidant, antibacterial, and toxicity of propolis particles produced by stingless bee Heterotrigona itama found in Brunei Darussalam, Heliyon 5 (2019) e02476, https://doi.org/10.1016/j.heliyon.2019.e02476.
[142] M.E.E.-D. Ibrahim, R.M. Alqurashi, Anti-fungal and antioxidant properties of propolis (bee glue) extracts, Int. J. Food Microbiol. 361 (2022) 109463, https://doi.org/10.1016/j.ijfoodmicro.2021.109463.
[143] I. AL-Ani, S. Zimmermann, J. Reichling, M. Wink, Antimicrobial activities of European propolis collected from various geographic origins alone and in combination with antibiotics, Medicines 5 (2018) 2, https://doi.org/10.3390/medicines5010002.
[144] T.N. Afata, R. Nemo, N. Ishete, G.T. Tucho, A. Dekebo, Phytochemical investigation, physicochemical characterization, and antimicrobial activities of Ethiopian propolis, Arab. J. Chem. 15 (2022) 103931, https://doi.org/10.1016/j.arabjc.2022.103931.
[145] D. Gumus, M. Kizil, Comparison of the reducing effects of blueberry and propolis extracts on heterocyclic aromatic amines formation in pan fried beef, Meat Sci. 186 (2022) 108746, https://doi.org/10.1016/j.meatsci.2022.108746.
[146] S.I. Anjum, A. Ullah, K.A. Khan, M. Attaullah, H. Khan, H. Ali, M.A. Bashir, M. Tahir, M.J. Ansari, H.A. Ghramh, N. Adgaba, C.K. Dash, Composition and functional properties of propolis (bee glue): a review, Saudi J. Biol. Sci. 26 (2019) 1695–1703, https://doi.org/10.1016/j.sjbs.2018.08.013.
[147] F.T. Correa, A.C. de Souza, E.A. de Souza Júnior, S.R. Isidoro, R.H. Piccoli, D.R. Dias, L.R. de Abreu, Effect of Brazilian green propolis on microorganism contaminants of surface of Gorgonzola-type cheese, J. Food Sci. Technol. 56 (2019) 1978–1987, https://doi.org/10.1007/s13197-019-03664-2.
[148] V. Bankova, B. Trusheva, M. Popova, Propolis extraction methods: a review, J. Apicult. Res. 60 (2021) 734–743, https://doi.org/10.1080/00218839.2021.1901426.
[149] L.S. Chua, Y.L. Chan, Z.Y. Tay, J. Soo, Water-soluble propolis extract as a natural preservative for jaboticaba juice, Food Biosci. (2023) 102651, https://doi.org/10.1016/j.fbio.2023.102651.
[150] K. Maroof, K.F. Chen, R.F.S. Lee, B.H. Goh, C.K. Mahendra, L.F. Siow, S.H. Gan, A preliminary study on phenolics, antioxidant and antibacterial activities of Acacia mangium and Garcinia mangostana propolis collected by Geniotrigona thoracica, Food Chemistry Advances 2 (2023) 100255, https://doi.org/10.1016/j.focha.2023.100255.
[151] K. Pobiega, K. Kraśniewska, J.L. Przybył, K. Bączek, J. Żubernik, D. Witrowa-Rajchert, M. Gniewosz, Growth biocontrol of foodborne pathogens and spoilage microorganisms of food by polish propolis extracts, Molecules 24 (2019) 2965, https://doi.org/10.3390/molecules24162965.
[152] S. Salwan, I. Passi, B. Kumar, Various analytical methods for estimation of potassium sorbate in food products: a review, Curr. Anal. Chem. 18 (2022) 977–988, https://doi.org/10.2174/1573411018666220820122912.
[153] N. Yazdanfar, L. Manafi, B. Ebrahiminejad, Y. Mazaheri, P. Sadighara, B. Basaran, S. Mohamadi, Evaluation of sodium benzoate and potassium sorbate preservative concentrations in different sauce samples in urmia, Iran, J. Food Protect. 86 (2023) 100118, https://doi.org/10.1016/j.jfp.2023.100118.
[154] J.-W. Chon, K.-H. Seo, H. Oh, D. Jeong, K.-Y. Song, Chemical and organoleptic properties of some dairy products supplemented with various concentration of propolis: a preliminary study, Journal of Dairy Science and Biotechnology 38 (2020) 59–69, https://doi.org/10.22424/jdsb.2020.38.2.59.
[155] S. Yerlikaya, H. Şen Arslan, Antioxidant and chemical effects of propolis, sage (Salvia officinalis L.), and lavender (Lavandula angustifolia Mill) ethanolic extracts on chicken sausages, J. Food Process. Preserv. 45 (2021) e15551, https://doi.org/10.1111/jfpp.15551.
[156] N. Liao, L. Sun, D. Wang, L. Chen, J. Wang, X. Qi, H. Zhang, M. Tang, G. Wu, J. Chen, R. Zhang, Antiviral properties of propolis ethanol extract against norovirus and its application in fresh juices, LWT 152 (2021) 112169, https://doi.org/10.1016/j.lwt.2021.112169.
[157] P. Velásquez, G. Montenegro, L.M. Valenzuela, A. Giordano, G. Cabrera-Barjas, O. Martin-Belloso, k-carrageenan edible films for beef: honey and bee pollen phenolic compounds improve their antioxidant capacity, Food Hydrocolloids 124 (2022) 107250, https://doi.org/10.1016/j.foodhyd.2021.107250.
[158] O. Anjos, R. Fernandes, S.M. Cardoso, T. Delgado, N. Farinha, V. Paula, L.M. Estevinho, S.T. Carpes, Bee pollen as a natural antioxidant source to prevent lipid oxidation in black pudding, LWT 111 (2019) 869–875, https://doi.org/10.1016/j.lwt.2019.05.105.
[159] M.L. Vică, M. Glevitzky, D.M. Tit, T. Behl, R.C. Heghedűş-Mîndru, D.C. Zaha, F. Ursu, M. Popa, I. Glevitzky, S. Bungău, The antimicrobial activity of honey and propolis extracts from the central region of Romania, Food Biosci. 41 (2021) 101014, https://doi.org/10.1016/j.fbio.2021.101014.
[160] V.B. Viera, N. Piovesan, K.I.B. Moro, A.S. Rodrigues, G. Scapin, C.S. da Rosa, E.H. Kubota, Preparation and microbiological analysis of Tuscan sausage with added propolis extract, Food Sci. Technol. 36 (2016) 37–41, https://doi.org/10.1590/1678-457X.0045.
[161] L.I. Mazamba, V.T. Solórzano, R.A. Solórzano, A. Pazmiño, G.C. Nevárez, Análisis de la inhibición de microorganismos proteolíticos en filetes de tilapia roja (Oreochromis spp) conservados con propóleo (Apis mellifera Linnaeus), La Granja 38 (2023) 17–32, https://doi.org/10.17163/lgr.n38.2023.02.
[162] A. Güngören, B. Patir, E. Özpolat, The effect of propolis application on quality properties of vacuum-packed hot smoked rainbow trout (Oncorhynchus Mykiss, Walbaum 1792) fillets during cold storage, LWT 184 (2023) 115084, https://doi.org/10.1016/j.lwt.2023.115084.
[163] J. Delgado, J. Mandujano, D. Reátegui, E. Ordoñez, Development of dark chocolate with fermented and non- fermented cacao nibs: total polyphenols, anthocyanins, antioxidant capacity and sensory evaluation, Sci. Agropecu. 9 (2018) 543–550, https://doi.org/10.17268/sci.agropecu.2018.04.10.
[164] D.H. Kim, E.W. Jeong, Y. Baek, H.G. Lee, Development of propolis extract-loaded nanoparticles with chitosan and hyaluronic acid for improving solubility and stability, LWT 181 (2023) 114738, https://doi.org/10.1016/j.lwt.2023.114738.
[165] G. Nayak, A. Sahu, S.K. Bhuyan, R. Bhuyan, D. Kar, A. Kuanar, A comparative study on antioxidant activity of propolis ethanolic extract and oil from different agroclimatic regions of Eastern India, Biocatal. Agric. Biotechnol. 50 (2023) 102685, https://doi.org/10.1016/j.bcab.2023.102685.
[166] L. Tavares, L. Santos, C.P. Zapata Noreña, Bioactive compounds of garlic: a comprehensive review of encapsulation technologies, characterization of the encapsulated garlic compounds and their industrial applicability, Trends Food Sci. Technol. 114 (2021) 232–244, https://doi.org/10.1016/j.tifs.2021.05.019.
[167] I. Hamed, M. Moradi, P. Ezati, L. O'Higgins, A.J. Meléndez-Martínez, R. Frleta Matas, V. Šimat, D.J. McClements, A.N. Jakobsen, J. Lerfall, Encapsulation of microalgal-based carotenoids: recent advances in stability and food applications, Trends Food Sci. Technol. 138 (2023) 382–398, https://doi.org/10.1016/j.tifs.2023.06.027.

[168] K. Pant, M. Thakur, H.K. Chopra, V. Nanda, Encapsulated bee propolis powder: drying process optimization and physicochemical characterization, LWT 155 (2022) 112956, https://doi.org/10.1016/j.lwt.2021.112956.
[169] C. Jansen-Alves, L. Martins Fonseca, F. Doring Krumreich, E.D.R. Zavareze, Applications of propolis encapsulation in food products, J. Microencapsul. 40 (2023) 567–586, https://doi.org/10.1080/02652048.2023.2274059.
[170] T. Sato, D. Mello, L. Vasconcellos, A.J.M. Valente, A. Borges, Chitosan-based coacervate polymers for propolis encapsulation: release and cytotoxicity studies, Int. J. Mol. Sci. 21 (2020) 4561, https://doi.org/10.3390/ijms21124561.
[171] D.G. Piedrahíta Márquez, C.A. Fuenmayor, H. Suarez Mahecha, Effect of chitosan-propolis edible coatings on stability of refrigerated cachama (Piaractus brachypomus) vacuum-packed fish fillets, Packag. Technol. Sci. 32 (2019) 143–153, https://doi.org/10.1002/pts.2422.
[172] L. Kamali Rousta, S. Bodbodak, M. Nejatian, A.P. Ghandehari Yazdi, Z. Rafiee, J. Xiao, S.M. Jafari, Use of encapsulation technology to enrich and fortify bakery, pasta, and cereal-based products, Trends Food Sci. Technol. 118 (2021) 688–710, https://doi.org/10.1016/j.tifs.2021.10.029.
[173] D.P. Cardona Tangarife, L.P. Patiño Arias, A.M. Ormaza Zapata, Aspectos tecnológicos de la microencapsulación de compuestos bioactivos en alimentos mediante secado por aspersión, CTA 22 (2021) 1–21, https://doi.org/10.21930/rcta.vol22_num1_art, 1899.
[174] Y. Cheng, B. Ang, C. Xue, Z. Wang, L. Yin, T. Wang, Q. Chen, Z. Wang, M. Zeng, W. Zhang, J. Chen, Z. He, Insights into the fermentation potential of pollen: manufacturing, composition, health benefits, and applications in food production, Trends Food Sci. Technol. 143 (2024) 104245, https://doi.org/10.1016/j.tifs.2023.104245.
[175] A.Ž. Kostić, D.D. Milinčić, M.B. Barać, M. Ali Shariati, Ž.L. Tešić, M.B. Pešić, The application of pollen as a functional food and feed ingredient—the present and perspectives, Biomolecules 10 (2020) 84, https://doi.org/10.3390/biom10010084.
[176] W. Han, X. Chai, Y. Liu, Y. Xu, C.-P. Tan, Crystal network structure and stability of beeswax-based oleogels with different polyunsaturated fatty acid oils, Food Chem. 381 (2022) 131745, https://doi.org/10.1016/j.foodchem.2021.131745.
[177] M. López-Pedrouso, J.M. Lorenzo, B. Gullón, P.C.B. Campagnol, D. Franco, Novel strategy for developing healthy meat products replacing saturated fat with oleogels, Curr. Opin. Food Sci. 40 (2021) 40–45, https://doi.org/10.1016/j.cofs.2020.06.003.
[178] S. Manzoor, F.A. Masoodi, F. Naqash, R. Rashid, Oleogels, Promising alternatives to solid fats for food applications, Food Hydrocolloids for Health 2 (2022) 100058, https://doi.org/10.1016/j.fhfh.2022.100058.
[179] J. Guo, L. Cui, Z. Meng, Oleogels/emulsion gels as novel saturated fat replacers in meat products: a review, Food Hydrocolloids 137 (2023) 108313, https://doi.org/10.1016/j.foodhyd.2022.108313.
[180] P. Selvasekaran, R. Chidambaram, Advances in formulation for the production of low-fat, fat-free, low-sugar, and sugar-free chocolates: an overview of the past decade, Trends Food Sci. Technol. 113 (2021) 315–334, https://doi.org/10.1016/j.tifs.2021.05.008.
[181] R. Zhang, T. Zhang, M. Hu, Y. Xue, C. Xue, Effects of oleogels prepared with fish oil and beeswax on the gelation behaviors of protein recovered from Alaska Pollock, LWT 137 (2021) 110423, https://doi.org/10.1016/j.lwt.2020.110423.
[182] E.J. Pérez-Monterroza, C.J. Márquez-Cardozo, H.J. Ciro-Velásquez, Rheological behavior of avocado (Persea americana Mill, cv. Hass) oleogels considering the combined effect of structuring agents, LWT - Food Sci. Technol. (Lebensmittel-Wissenschaft -Technol.) 59 (2014) 673–679, https://doi.org/10.1016/j.lwt.2014.07.020.
[183] A.J. Martins, J.M. Lorenzo, D. Franco, M. Pateiro, R. Domínguez, P.E.S. Munekata, L.M. Pastrana, A.A. Vicente, R.L. Cunha, M.A. Cerqueira, Characterization of enriched meat-based pâté manufactured with oleogels as fat substitutes, Gels 6 (2020) 17, https://doi.org/10.3390/gels6020017.
[184] Y. Guo, Z. Cai, Y. Xie, A. Ma, H. Zhang, P. Rao, Q. Wang, Synthesis, physicochemical properties, and health aspects of structured lipids: a review, Compr. Rev. Food Sci. Food Saf. 19 (2020) 759–800, https://doi.org/10.1111/1541-4337.12537.
[185] Z. Zhang, H. Wang, Y. Shu, X. Zhang, T. Yang, W. Qi, H.-N. Xu, Improving the freeze-thaw stability of pork sausage with oleogel-in-water Pickering emulsion used for pork backfat substitution, LWT 180 (2023) 114698, https://doi.org/10.1016/j.lwt.2023.114698.
[186] M. Moghtadaei, N. Soltanizadeh, S.A.H. Goli, Production of sesame oil oleogels based on beeswax and application as partial substitutes of animal fat in beef burger, Food Res. Int. 108 (2018) 368–377, https://doi.org/10.1016/j.foodres.2018.03.051.
[187] P. Sun, B. Xia, Z.-J. Ni, Y. Wang, E. Elam, K. Thakur, Y.-L. Ma, Z.-J. Wei, Characterization of functional chocolate formulated using oleogels derived from β-sitosterol with γ-oryzanol/lecithin/stearic acid, Food Chem. 360 (2021) 130017, https://doi.org/10.1016/j.foodchem.2021.130017.
[188] C.R. Balcázar-Zumaeta, E.M. Castro-Alayo, L.D. Muñoz-Astecker, I.S. Cayo-Colca, F. Velayarce-Vallejos, Food Technology forecasting: a based bibliometric update in functional chocolates, Heliyon 9 (2023), https://doi.org/10.1016/j.heliyon.2023.e19578.
[189] R. Airoldi, T.L.T. da Silva, J.N.R. Ract, A. Foguel, H.L. Colleran, S.A. Ibrahim, R.C. da Silva, Potential use of carnauba wax oleogel to replace saturated fat in ice cream, JAOCS (J. Am. Oil Chem. Soc.) 99 (2022) 1085–1099, https://doi.org/10.1002/aocs.12652.
[190] M. Pang, Z. Shi, Z. Lei, Y. Ge, S. Jiang, L. Cao, Structure and thermal properties of beeswax-based oleogels with different types of vegetable oil, Grasas Aceites 71 (2020), https://doi.org/10.3989/gya.0806192 e380–e380.
[191] W. Han, X. Chai, F. Zaaboul, C.-P. Tan, Y. Sun, C. Liu, Y. Liu, Beeswax crystals form a network structure in highly unsaturated oils and O/W emulsions under supersaturation and cool temperature conditions, LWT 164 (2022) 113594, https://doi.org/10.1016/j.lwt.2022.113594.
[192] A.K. Baswal, H.S. Dhaliwal, Z. Singh, B. Mahajan, A. Kalia, K.S. Gill, Influence of carboxy methylcellulose, chitosan and beeswax coatings on cold storage life and quality of Kinnow Mandarin fruit, Sci. Hortic. 260 (2020) 108887, https://doi.org/10.1016/j.scienta.2019.108887.
[193] H. Huang, C. Huang, C. Xu, R. Liu, Development and characterization of lotus-leaf-inspired bionic antibacterial adhesion film through beeswax, Food Packag. Shelf Life 33 (2022) 100906, https://doi.org/10.1016/j.fpsl.2022.100906.
[194] B. Zewdie, T.T. Shonte, K. Woldetsadik, Shelf life and quality of tomato (Lycopersicon esculentum Mill.) fruits as affected by neem leaf extract dipping and beeswax coating, Int. J. Food Prop. 25 (2022) 570–592, https://doi.org/10.1080/10942912.2022.2053709.
[195] T.A.A. Nasrin, M.A. Rahman, M.S. Arfin, M.N. Islam, M.A. Ullah, Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage, Journal of Agriculture and Food Research 2 (2020) 100019, https://doi.org/10.1016/j.jafr.2019.100019.
[196] P. Peeters, E. Çakmak, J. Guiver, Current issues in tourism: mitigating climate change in sustainable tourism research, Tourism Manag. 100 (2024) 104820, https://doi.org/10.1016/j.tourman.2023.104820.
[197] A. Tohidimoghadam, A. PourSaeed, M. Bijani, R.E. Samani, Rural sustainable livelihood resilience to climate change: a strategic analysis, Environmental and Sustainability Indicators (2023) 100292, https://doi.org/10.1016/j.indic.2023.100292.
[198] F. Requier, N. Pérez-Méndez, G.K.S. Andersson, E. Blareau, I. Merle, L.A. Garibaldi, Bee and non-bee pollinator importance for local food security, Trends Ecol. Evol. 38 (2023) 196–205, https://doi.org/10.1016/j.tree.2022.10.006.
[199] X. Shi, C. Ma, W. Gustave, M.C. Orr, Z. Yuan, J. Chen, G. Yang, Z. Niu, Q. Zhou, C. Xia, A. Luo, C. Zhu, The impact of heavy metal pollution on wild bee communities in smallholder farmlands, Environ. Res. 233 (2023) 116515, https://doi.org/10.1016/j.envres.2023.116515.
[200] R. Mohd Ariff, X.Y. Chai, L.S. Chang, S. Fazry, B.A. Othman, A.S. Babji, S.J. Lim, Recent trends in Kombucha: conventional and alternative fermentation in development of novel beverage, Food Biosci. 53 (2023) 102714, https://doi.org/10.1016/j.fbio.2023.102714.
[201] G. Santagata, S. Mallardo, G. Fasulo, P. Lavermicocca, F. Valerio, M. Di Biase, M. Di Stasio, M. Malinconico, M.G. Volpe, Pectin-honey coating as novel dehydrating bioactive agent for cut fruit: enhancement of the functional properties of coated dried fruits, Food Chem. 258 (2018) 104–110, https://doi.org/10.1016/j.foodchem.2018.03.064.
[202] A. Ahuja, V. Kumar Rastogi, Spray coating of edible insect waxes for liquid food packaging, Appl. Surf. Sci. 624 (2023) 157150, https://doi.org/10.1016/j.apsusc.2023.157150.
[203] E. Morales, N. Iturra, I. Contardo, M. Quilaqueo, D. Franco, M. Rubilar, Fat replacers based on oleogelation of beeswax/shellac wax and healthy vegetable oils, LWT 185 (2023) 115144, https://doi.org/10.1016/j.lwt.2023.115144.
[204] T.A.A. Nasrin, M.S. Arfin, MdA. Rahman, M.M. Molla, A.A. Sabuz, M.A. Matin, Influence of novel coconut oil and beeswax edible coating and MAP on postharvest shelf life and quality attributes of lemon at low temperature, Measurement, Food 10 (2023) 100084, https://doi.org/10.1016/j.meafoo.2023.100084.

[205] Z. Pérez-Bassart, A. Reyes, A. Martínez-Abad, A. López-Rubio, M.J. Fabra, Feasibility of Agaricus bisporus waste biomass to develop biodegradable food packaging materials, Food Hydrocolloids 142 (2023) 108861, https://doi.org/10.1016/j.foodhyd.2023.108861.
[206] F.T. da Silva, F.N. dos Santos, L.M. Fonseca, E.J.D. de Souza, H.C. dos Santos Hackbart, K.G. da Silva, B. Biduski, E.A. Gandra, A.R.G. Dias, E. da Rosa Zavareze, Oleogels based on germinated and non-germinated wheat starches and orange essential oil: application as a hydrogenated vegetable fat replacement in bread, Int. J. Biol. Macromol. (2023) 126610, https://doi.org/10.1016/j.ijbiomac.2023.126610.
[207] J. Nutter, X. Shi, B. Lamsal, N.C. Acevedo, Plant-based bigels as a novel alternative to commercial solid fats in short dough products: textural and structural properties of short dough and shortbread, Food Biosci. 54 (2023) 102865, https://doi.org/10.1016/j.fbio.2023.102865.
[208] M. Van Espen, J.H. Williams, F. Alves, Y. Hung, D.C. de Graaf, W. Verbeke, Beekeeping in Europe facing climate change: a mixed methods study on perceived impacts and the need to adapt according to stakeholders and beekeepers, Sci. Total Environ. 888 (2023) 164255, https://doi.org/10.1016/j.scitotenv.2023.164255.
[209] B. Demirci, S. Durna Dastan, The moisture determination of bee pollen from Sivas Province in Anatolia and their antiproliferative activities in MCF-7 cell line, Central Asian Journal of Medical and Pharmaceutical Sciences Innovation 3 (2023) 22–28, https://doi.org/10.22034/CAJMPSI.2023.01.03.
[210] N. Abdulraziq, Bee Venom and its Potential to Treat Cancer, 2020. http://repository.limu.edu.ly/handle/123456789/1738. (Accessed 2 September 2023).
[211] P. Pandey, F. Khan, M.A. Khan, R. Kumar, T.K. Upadhyay, An updated review summarizing the anticancer efficacy of melittin from bee venom in several models of human cancers, Nutrients 15 (2023) 3111, https://doi.org/10.3390/nu15143111.
[212] F. Şengül, H. Vatansev, Overview of apitherapy products: anti-cancer effects of bee venom used in apitherapy, International Journal of Traditional and Complementary Medicine Research 2 (2021) 36–48.
[213] A. Rana, H.K. Bajwa, Therapeutics of bioactive compounds from medicinal plants and honeybee products against cancer: phytotherapy and apitherapy as alternatives to chemotherapy, J. Sci. Ind. Res. 82 (2023) 805–817, https://doi.org/10.56042/jsir.v82i08.1895.