

Review

Antibacterial activity of honey: A review of honey around the world

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Nectar is a natural product collected by bees from which honey is produced. Honey possesses antibacterial activity and is classified as peroxide and non-peroxide components. The contribution of these components is discussed briefly to ascertain their contribution to the antibacterial activity. Data of origin and floral sources of honey and antimicrobial activity against different bacteria species are summarized. It was concluded that inhibition of growth of bacteria is principally due to the peroxide effect, which is very common in honey wide world because it is a derivative compound from bees. Although the peroxide effect could be reduced when honey is processed, the application of hazard analysis and critical control points could prevent the reduction. The research carried out so far indicates that honey is successfully used to control some food pathogens and owing to this, it could be used in food preservation.

Key words: Antibacterial activity, honey, peroxide activity, non-peroxide activity.

INTRODUCTION

Honey is a nutritive food used widely in the food industry, which provides energy to the organism due its high percentage of carbohydrates, which are easily assimilated. Besides this, it has been used for wound dressing since ancient times (Ransome, 1937; Allen et al., 1991), although antibacterial properties were reported by Sackett (1919) and Allen et al. (1991). Honey has been used as a topical antibacterial agent for the treatment of surface infections such as ulcers and bed sores (Blomfield, 1973; Keast Butler, 1980) and those resulting from burns, injuries and surgical wounds

(McInerney, 1990). The use of honey as a medicine has continued into the present day-medicine (Mathews and Binnintong, 2002).

Honey is produced from the nectar of flowers (floral honey) or the secretions from plants and/or excretions of insects, called honeydew. Bees gather these sugary substances, enrich them with their own substances and store them in the honeycombs.

A lot of the compositional and quality studies have been carried out on floral honeys produced by honey bees (*Apis spp.*) and the criteria and quality standards

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are well specified in the Codex Alimentarius. Other kinds of honeys, such as honey from stingless bees, native of the Americas, have been less studied and consequently standards of quality control of stingless honeys are not yet established in the countries where they are produced (Souza, 2006; Dardon and Enriquez, 2008; Zamora and Arias, 2011).

Honey is composed of about 181 components and is basically a solution supersaturated in sugars, of which fructose (38%) and glucose (31%) are the most important (Gheldof et al., 2002); the moisture content is about 17.7%, total acidity 0.08% and ash content is 0.18% (Nagai et al., 2006). In addition, there is a great variety of minor components, including phenolic acids, flavonoids, the enzymes glucose oxidase and catalase, ascorbic acid, carotenoids, organic acids, amino acids, proteins and alfa-tocopherol (Ferrerres et al., 1993). However, the composition of honey varies depending on many factors such as the floral source, climate, environmental conditions and the processing it undergoes as pasteurization or storage (Gheldof et al., 2002; Azeredo et al., 2003). Honey is a unique food product containing bioactive compounds derived from bees and plants. These bioactive compounds could be linked to the antimicrobial activity which has the capacity of destroying or inhibiting the growth of some pathogenic vegetative microorganisms (Allen et al., 1991; Nzeako and Hamdi, 2000; Chick et al., 2001). Even though the natural antimicrobials could be an interesting tool for controlling pathogenic microorganisms, the antibacterial effect of honeys is not completely understood.

ANTIMICROBIAL PROPERTIES OF HONEY

Studies describing growth inhibition of numerous bacteria of clinical significance have been performed using honey (Molan, 1992; Taormina et al., 2001; Mundo et al., 2004; Tumini et al., 2005; Baltrusaityte et al., 2007; Cruzado Razco et al., 2007; Murat Küçük et al., 2007; Hyungjae et al., 2008; Adetuyi et al., 2009; Tajik and Jalali, 2009; Osho and Bello, 2010; Halawani and Shohayeb, 2011). Many investigations reported that the antimicrobial activity of honey is due to physicochemical properties such as high content of reducing sugars, high viscosity, high osmotic pressure, low pH, low water activity, low protein content and presence of hydrogen peroxide (Molan and Cooper, 2000). The main antibacterial factor in honey is hydrogen peroxide (White et al., 1963; Allen et al., 1991; Molan, 1992; National Honey Board USA, 2002; Sulaiman Alnaimat et al., 2012), which is produced by the glucose-oxidase action. The honey-glucosidase, which is secreted by the hypopharyngeal glands, breaks bee glucose to form gluconic acid and hydrogen peroxide. The little water available and the acid pH makes glucosidase inactive, but the activity is resumed when the honey is diluted in water.

Glucosidase levels in honey may vary depending on bee health and its diet (Alaux et al., 2010). However, the amount of hydrogen peroxide produced in a sample of honey is not only determined by glucosidase levels, honey can contain catalase, peroxidases and antioxidant as gallic acid and caffeic acid, hydrogen peroxide can degrade or interfere with their ability to damage the cell's bacterium (Weston, 2000; Pyrzynska and Biesaga, 2009). Some reports show that the presence of methylglyoxal (MGO) can modify some honey proteinaceous compounds and therefore can affect the glucosidase activity (Majtan et al., 2012).

The level of peroxide in honey is determined also by the presence of catalase, which originates from the pollen of plants (Weston, 2000). The amount of hydrogen peroxide is affected by light, temperature and oxygen, which might vary according to the processing and storage conditions of honey. If these are not adequate, the main enzyme which generates hydrogen peroxide is inactivated and consequently the effect of hydrogen peroxide as antibacterial factor could be reduced (Dustman, 1979).

Considering studies by Chen (2012) on honey samples heated at temperatures 45°C for 8 h and a filtering process, it may be concluded that the amount of hydrogen peroxide is not indicator of antimicrobial activity but is related to the stability of hydrogen peroxide when honey is subjected to heating and filtration, but the researches shows that more observations should be made to corroborate this observation.

In some cases, the antibacterial activity is due entirely to the non-peroxide components such as acidity, osmolarity, flavonoids, phenolic compounds and lysozyme (Allen et al., 1991). An advantage of non-peroxide antibacterial activity is that it remains intact after storage of honey for long periods of time (Bogdanov, 1984) and does not change with different conditions of heat and light (Gonnet and Lavie, 1960; Bogdanov, 1984). In relation to non-peroxide and non-active compounds of honey, Yatsunami and Echigo (1984) found that low pH honey, in addition to the high honey osmolarity, were responsible for the antibacterial activity.

Different studies have claimed that honeys contain bioactive compounds such as lysozyme, a well known antibacterial agent (Estrada et al., 2005), however some honeys do not have lysozyme activity (Bogdanov, 1984). In addition, the antibacterial flavonoid pinocembrin is present in honey but its concentration and contribution to the non-peroxide antibacterial activity of honey is not significant (Bogdanov, 1989). On the other hand, volatile substances with antibacterial activity have also been isolated from honeys (Toth et al., 1987), but their quantitative contribution to the antibacterial action of the honey has not been examined. Other substances with non-peroxide activity were extracted by organic solvents from honeys, but it was not possible to identify the chemical nature of these substances (Radwan et al.,

Table 1. Summary of antibacterial activity of honeys worldwide.

Honey origin	Type of honey	Composition	Antimicrobial activity against	References
New Zealand	Monofloral	<i>Kunzea ericoides</i> (White tea Tree) <i>Leptospermum scoparium</i> (Manuka) <i>Calluna vulgaris</i> (Heather) <i>Weinmannia racemosa</i> (Kāmahi)	<i>Staphylococcus aureus</i>	Allen et al. (1991)
Different countries	Monofloral	<i>Ziziphus spina-christi</i> (Christ's Thorn Jujube) <i>Nigella sativa</i> (Black cumin, fennel flower) <i>Citrus spp.</i> (Citrus) <i>Trifolium alexandrinum</i> (Egyptian clover, berseem clover)	<i>Salmonella enteritidis</i>	Halawani and Shohayeb (2011)
Buenos Aires, Argentina	Multifloral	NS	<i>S. aureus coagulasa</i>	Tabera et al. (2006)
Argentina	Monofloral	<i>Prosopis sp.</i> (Mezquite tree) <i>Eucalyptus sp.</i> <i>Baccharis sp.</i> (Chilca)	<i>S. aureus</i> ATCC 29213 <i>Pseudomonas aeruginosa</i> ATCC 227853 <i>Escherichia coli</i> ATCC 35218	Maidana et al. (2008)
Buenos Aires, Argentina	NS	NS	<i>E. coli</i>	Fangio et al. (2007)
USA Lancaster	Monofloral	<i>Fagopyrum sp.</i> (Buckwheat) <i>Vaccinium sp.</i> (Blueberry) <i>Helianthus annuus</i> (Sunflower) <i>Trifolium sp.</i> (Clover) <i>Persea sp.</i> (Avocado)	<i>E. coli</i> O157:H7 3402, H330, V302, G8430 F6129, 10304-98, 10305-98 <i>S. aureus</i> ATCC 13565, ATTC 27664, ATTC 6538 <i>S. typhimurium</i> <i>Shigella .sonnei</i> <i>Listeria monocytogenes</i> G1091, H0222, V7	Taormina et al. (2011)
Iran	Natural honey	NS	<i>S. aureus</i> ATCC 25923, 25922, <i>P. aeruginosa</i> ATCC <i>E. coli</i> ATCC 25922	Tajik and Jalali et al. (2009)
Lithuania	Monofloral	<i>Salix alba L.</i> (White Willow) <i>Salix caprea L.</i> (Goat willow) <i>Brassica napus</i> (Rape)	<i>S. aureus</i> , <i>S. epidermidis</i>	Baltrusaityte et al. (2007)
Nigeria	NS	NS	<i>S. aureus</i> , <i>Proteus mirabilis</i> , <i>E. Coli</i> , <i>Salmonella dysenteriae</i>	Adetuyi et al. (2009)
Nigeria	NS	NS	<i>S. aureus</i> , <i>Pseudomona aeruginosa</i> , <i>E. coli</i> , <i>Klebsiella pneumoniae</i> , <i>Bacillus subtilis</i>	Osho et al. (2010)
Malaysia	NS	NS	<i>Salmonella Typhi</i> , <i>Shigella sonnei</i> , <i>S. aureus</i> ATCC25923, <i>E. coli</i> ATCC25922, <i>Salmonella pyogenes</i>	Tumini et al. (2005)

Table 1. Contd.

Not specified	NS	<i>Serenoa</i> sp. (Saw palmetto) sp. (Buckwheat) <i>Leptospermum scoparium</i> (Manuka) <i>Melaleuca</i> sp.	<i>Fagopyrum</i> <i>Grindelia</i> sp. (Tarweed) (Paper bark tea tree)	<i>B. Stearothermophilus</i> , <i>S. aureus</i> ATCC 9144, <i>Aspergillus faecalis</i> , <i>Lactobacillus acidophilus</i> , <i>E. coli</i> 157:H7	Mundo et al. (2004)
Turkey	Monofloral Multifloral	<i>Castanea sativa</i> (Chestnut) sp. (Great Laurel) <i>microcephalus</i>	<i>Rhododendron</i> <i>Astragalus</i> (Thyme). <i>Thymus vulgaris</i>	<i>Staphylococcus aureus</i> ATCC 25923 <i>Bacillus subtilis</i> ATCC 6630 <i>Helicobacter pylori</i> ATCC 49503 <i>Candida tropicalis</i> ATCC 13803 <i>C. albicans</i> ATCC 10231	Murat Küçük et al. (2007)
Colombia	NS	NS		<i>Salmonella enteritidis</i> , <i>E.coli</i> , <i>S. aureus</i>	Cruzado Razco et al. (2007)
Chile	Monoflora	<i>Quillaja saponaria</i>	(Soap Bark tree)	<i>E. coli</i> ATCC 25922, <i>Pseudomona aeruginosa</i> ATCC 27853, <i>Salmonella typha</i> STH 2370, <i>S. aureus</i> ATCC 25923, <i>Streptococcus pneumoniae</i> (Tipo β), <i>Vibrio cholerae</i> ISP, <i>Pectobacterium carotovorum</i>	Montenegro et al. (2009)

Common names of plant species are indicated in parenthesis. Data are inferred from published articles. Where possible, composition of honey is given. Monofloral refers to the presence of one dominant pollen in the honey sample (at least 45%). NS=not specified.

1984).

A clear example of non-peroxide antibacterial activity is Manuka honey that is produced from the *Leptospermum scoparium* tree and similar *Leptospermum* species in New Zealand. Those honeys have an antibacterial component identified as methylglyoxal (Adams et al., 2008; Mavric et al., 2008), which is formed in honey from dihydroxyacetone present in Manuka nectar (Adams et al., 2009).

Kwakman et al. (2010) have shown for first time that honey with a bee origin and antimicrobial peptide called defensin, has an antibacterial effect, and this effect is attributed to the peptide activity. Bee defensin-1 was identified in the hemolymph of honeybees (Klaudiny et al., 2005) and was isolated from the royal jelly (Fujiwara et al., 1990) which is the food source for bee

queen larvae.

Most literature sources indicate that antibacterial activity of honey depends considerably on the floral source. The botanical composition of honey could be distinguished, if honey contained one type of predominate pollen which could be classified as monoflora, when no predominant pollen is considered as multiflora. The relation between botanical origin and antibacterial activity has been extensively researched and is summarized in the Table 1. The antibacterial activity of honey has been mainly tested against pathogenic bacteria in human being and food products. Most works listed in Table 1 have shown that the antibacterial activity has been done by peroxide effect.

The inhibitory action of thirty four honey samples from apiarists throughout Lithuania was tested

against *Staphylococcus aureus* and *Staphylococcus epidermidis* by the agar well diffusion method (Table 1). It was found that antibacterial activity of tested honey samples was considerably dependent on hydrogen peroxide formation, but the floral source of honey and bacterial culture were the two other factors related to antibacterial activity. Taormina et al. (2001) tested antibacterial activity from six floral sources against *Escherichia coli* O157H7, *Salmonella thyphimurium*, *Shigella sonnei*, *Listeria monocytogenes*, *S. aureus* and *Bacillus cereus*, by the disc diffusion test and they showed that the development of inhibition zones depends on the concentration of honey used in the test as well as the tested pathogen.

Growth of *B. cereus* was least affected by honey diluted 25% when compared with others

bacteria.

The color of honey is another characteristic associated with floral source. It was also found that darker colored honeys were generally inhibitory than light colored honeys. In contrast to these results, Halawani and Shohayeb (2011) have shown that there was no relationship between color and antibacterial activity of honey, some honeys of light coloration like orange blossom and clover, were more active as antibacterial against *Salmonella enteritidis* than darker studied honeys.

Some compounds with antioxidant activity such as tocopherol are present in some nectar, for example tamarind nectar. It has been shown that honeys with low levels of phenol and tocopherol had the highest antibacterial activity against clinical isolates of *S. aureus*, *Proteus mirabilis*, *E. coli* and *Salmonella dysenteriae* (Adetuyi et al., 2009).

In Argentina, studies were carried out to evaluate the antibacterial activity of multifloral honey from the stingless bees (*Plebeia wittmanni* and *Tetragonisca angustula fiebrigi*). It was shown that *E. coli* was inhibited only by antibacterial effect of honey from *P. wittmanni* (Sgariglia et al., 2010).

Antibacterial effects of honeys as compared to some antibiotics

Osho and Bello (2010) compared the antibacterial effect *in vitro*, of amoxicillin, tetracyclin and chloramphenicol antibiotics versus the antibacterial effects of two honeys solution of different concentrations (5, 25, 50 and 100%) against *S. aureus*, *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella pneumoniae*, *Bacillus subtilis* by the agar diffusion method. Both honeys tested were effective at 25 and 100% against all the microorganisms evaluated. In the same way, comparisons of antimicrobial activity of honey with sulfadimidine *in vitro*, against *S. aureus*, *P. aeruginosa* and *E. coli* were made by Tajik and Jalali (2009). The most sensitive organism to honey and sulfadimidine was *S. aureus*. Even though honey samples produced less inhibition zones than antibiotics, IT could be considered as an antibacterial agent.

CONCLUSIONS

Different works have shown that honey has broad-spectrum antibacterial activity against Gram positive and negative bacteria, which could confer nutraceutical properties. The activity against *S. aureus*, *E. coli* and *Salmonella* sp. has been expressed despite honey originating from different floral sources and countries. The inhibition of growth in those bacteria is principally due to the peroxide effect, which is very common in honey worldwide, and as it is a derivative compound from

bees, it is expected that it is present in all honeys. Since the peroxide effect is reduced when honey is processed, the antibacterial capacity of honey could be affected. Nowadays, hazard analysis and critical control point has been implemented, so that if quality norms are applied, it is expected that hydrogen peroxide should not vary greatly, and consequently the glucose-oxidase enzyme is not degraded. Future studies to evaluate the peroxide activity of honey after pasteurization should be carried out.

Although, the phenomenon of non-peroxide antibacterial activity has been demonstrated in some honeys, more research is necessary to understand the compounds that are related to non peroxide activity, and the kind of honey it is expressed.

The research carried out summarizes some of the investigation in different parts of the world, testing different botanical origins of honeys against major pathogens in food and clinical level.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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