

**Review****Potential biochemical effects of honey in oral health care: a review**

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Honey is a natural flower extract rich in healthy components including fructose, glucose, and various oligosaccharides. In addition, it comprises of proteins, enzymes, trace elements, vitamins, and polyphenols. Honey has a long history for its uses in medicinal purposes. However, its benefits on oral health have been overlooked till date. The main aim of this review is to address the benefits of honey in oral cavity, which have been identified in previous studies to have anti-cariogenic and anti-plaque; and also, for the treatment of cancer-induced mucositis and xerostomia.

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**Introduction**

Honey is a natural product comprising of flower nectar produced by honeybees. Honeybees ingest extracts from various flowers which are later digested to produce fructose and glucose. The extract ingested by honeybees is later regurgitated and transferred into the mouth of another bees until honey is converted into raw form. The whole process takes approximately 20 minutes. Later, the raw form of honey is placed in the honeycomb cells, and sealed by flapping the wings (Nicolson and Human, 2008; Zhu *et al.*, 2016).

Chemically, honey is composed of 17 - 20% water with other contents including flavour and colour. Honey colour is dependent on the types of flowers from which the extract has been taken, and it can vary from being colourless, straw-like, or black (Ahmad *et al.*, 2017). Honeybees can obtain extract from one or many types of flowers. Depending on the number of flowers involved, honey can be classified as mono- or multi-floral (Ahmad *et al.*, 2017). Natural honey is thought to comprise of more than 200 compounds, with few having pharmacological effect on human health. Honey mainly comprises of four components: (i) sugary content of various types of approximately 90 - 95%, (ii) organic acids, (iii) minerals, and (iv) water as shown in Figure 1 (Ezz El-Arab *et al.*, 2006; Eteraf-Oskouei and Najafi, 2013; Gašić *et al.*, 2017; Ahmed *et al.*, 2018; Khan *et al.*, 2018).

Honey has a long history with both medicinal and food uses in various ancient civilisations such as Chinese, Egyptians, Indians, Romans, and Assyrians (Eteraf-Oskouei and Najafi, 2013). It has sweetened taste and high nutritional values as reported by Aristotle, Hippocrates, and Arabs; and further by Ayurvedic physician who reported its benefits against numerous disorders (Bansal *et al.*, 2005; Eteraf-Oskouei and Najafi, 2013). Keeping in view of the uses of honey in ancient times, and the increasing microbial resistance against anti-microbial drugs, scientists are investigating the potential role of honey for medicinal use. It has been reported that honey has many beneficial pharmacological effects for the treatments of various injuries and illnesses (Figure 2) (Bansal *et al.*, 2005; Eteraf-Oskouei and Najafi, 2013). Previous studies have been conducted to investigate the potential effects of honey in oral health care, and this is the main focus of this review.

**Oral health**

Oral cavity is the beginning of the gastro-intestinal system. It houses hard and soft oral tissues, saliva, and oral micro-flora, thus creating the oral environment. The environment is constantly affected by changing conditions associated with food intake and its processing - mechanical and biochemical, which is the beginning of its digestion. The oral cavity possesses a distinctive ecosystem as a host environ, and it supports the growth and establishment of a variety of

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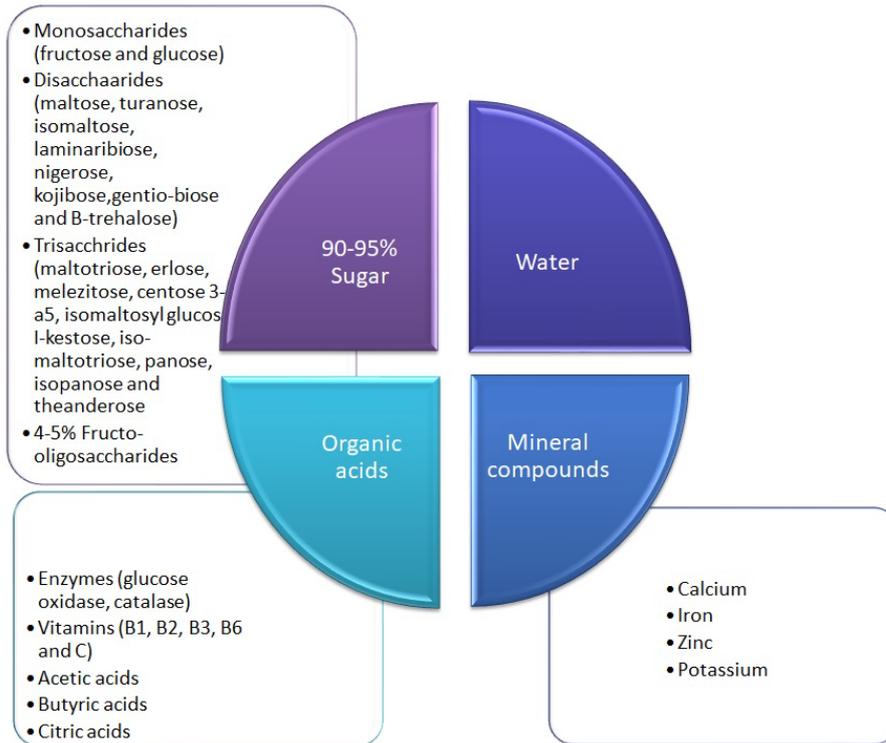


Figure 1. Composition of honey.

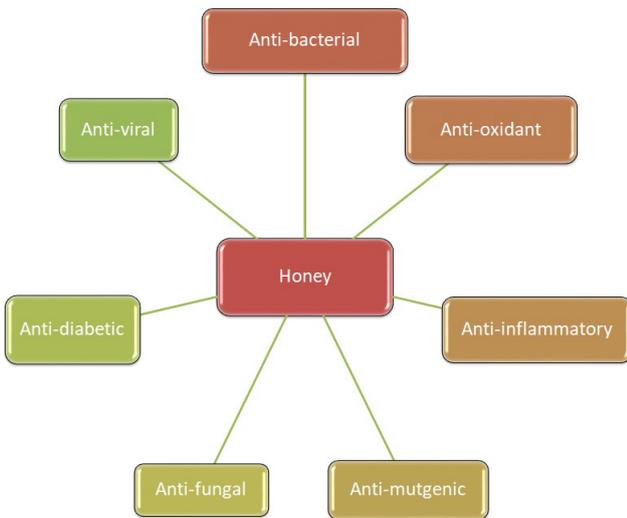


Figure 2. Pharmacological effects of honey.

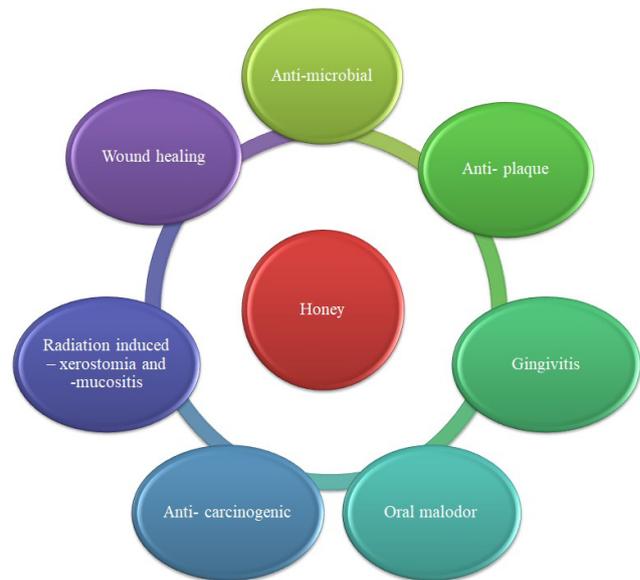


Figure 3. Pharmacological effects of honey on oral health.

micro-flora. The hard and soft structures in oral cavity include cheeks, tongue, gingivae, and teeth which provide sites for the adherence and subsequently growth of microorganisms. The oral cavity plays vital role in relation to mental conditions, in particular with speech and chewing (Jin *et al.*, 2016). The effects of honey against some of the most common oral diseases are illustrated in Figure 3 (Baltas *et al.*, 2016; Kolayli *et al.*, 2016).

*Anti-microbial effect*

An extensive variety of bacteria

(approximately 500 - 700 species) inhabit and colonise the oral cavity (Marsh and Martin, 2009). Different populations of bacteria are concomitant with different sites within the mouth, and their compositions also rely on the anatomical locality. For instance, the bacterial consortium which colonises teeth is different to that which colonises the soft tissues like tongue and buccal mucosa (Mager *et al.*, 2003). The population of these commonly found bacteria with respect to their

anatomical location remains stable (Marsh and Martin, 2009) and non-pathogenic under normal conditions, until any discrepancy happens which leads to the impairment of the host's defences due to any underlying illness/pathology. In a healthy individual, higher count of simple Gram-positive bacteria is observed; whereas in unhealthy conditions, higher content of Gram-negative bacteria is observed (Scannapieco, 2013). Honey has been reported to be effective against approximately 60 bacterial species (Gram-positive, Gram-negative, aerobic, and anaerobic), including one of the most common active bacteria, *Streptococcus mutans* which is related to dental caries (Asadi-Pooya *et al.*, 2003; Bansal *et al.*, 2005; Beena *et al.*, 2018). The most important point pertinent to natural honey till date is that bacteria are not observed to develop resistance against honey, unlike against antibiotics commercially available in the market (Henriques *et al.*, 2011). The possible reason for continued sensitivity among the microorganisms towards honey could be that rather than acting on the bacterial cell wall or intracellular metabolism, honey has a bacteriostatic effect while having high sugar content and low pH (Emsen, 2007; Ajibola *et al.*, 2012). Furthermore, it is observed to have bactericidal effect attributed to the presence of hydrogen peroxide (Emsen, 2007; Mandal *et al.*, 2010; Ajibola *et al.*, 2012).

#### *Anti-plaque effect*

The dental hard tissue in oral cavity (tooth) plays a vital role in mastication of food. It has a suitable structure for the colonisation of oral microorganisms and oral biofilm formation. A natural tooth comprises of pulp, cementum, dentine, and enamel (Nanci, 2014; Fehrenbach and Popowics, 2015). Being the outermost layer of the tooth, "dental enamel" is the only part that is exposed to the oral environment under normal condition. Tooth offers surfaces such as pits and fissures that facilitate microbial growth and colonisation. The surface of tooth normally favours the habitation of aerobic, facultative, and anaerobic microorganisms (Samaranayake, 2002; Aruni *et al.*, 2015). Oral health maintenance can only be attained by taking an effective oral hygiene measures on regular basis. A toothbrush is the most used device or tool to eradicate the dental plaque. When performed with an adequate skill and duration of time, manual brushing is highly effective. However, for most reasons, neither of these criteria is fulfilled like in the case of pits, fissures, and interproximal spaces; while orthodontic appliances such as dental floss, toothpicks, mini brushes, and interdental brushes are used to compensate an improper brushing. Powered

toothbrushes with a rotating, oscillating, or sonic action are also available in the market, and efficiently remove plaque and reduce gingivitis (Tritten and Armitage, 1996; Ho and Niederman, 1997; Moritis *et al.*, 2002; Biesbrock *et al.*, 2008).

Chemotherapeutic agents have been formulated in order to contribute to the control of gingivitis and plaque, according to the established guidelines by The American Dental Association. Nayak *et al.* (2010) has demonstrated anti-plaque effect and reduction of acid production by the use of Manuka honey.

#### *Effect on gingivitis*

Inflammation of the gingival tissue due to microbial colonisation in the dental plaque is referred as gingivitis, with clinical features showing gingival bleeding, loss of "knife edge papilla", stippling, and orange peel appearance. Gingivitis if treated with good oral hygiene practice is considered as a reversible condition, but failure can lead to periodontal diseases leading to loss of alveolar bone and periodontal ligaments attachment. The microbial content from the dental plaque migrates towards the apex of the tooth, stimulating inflammation similar to that observed in wounds (Nayak *et al.*, 2010). Manuka honey when used on wounds has been observed to have rapid anti-bacterial effect, thus reducing inflammation (Nayak *et al.*, 2010). Previous study conducted a randomised controlled trial to evaluate the effect of chewable honey on pH, microbial count, and microbial growth in comparison to sucrose on 20 orthodontically treated female patients (Atwa *et al.*, 2014). It was observed that pH did not go below critical pH of enamel with respect to saliva (5.2 - 5.4). Furthermore, they also observed the bactericidal and bacteriostatic effects of honey (Atwa *et al.*, 2014). Later, another study was conducted to compare the effect of Manuka and raw honey with chlorohexidine mouthwash, and they reported a promising effect of naturally occurring honey-based mouth rinses on dental plaque and gingivitis (Singhal *et al.*, 2018).

#### *Effect on oral malodour (halitosis)*

The word halitosis is derived from Latin word for breath - "halitus"; and referred as oral malodour, "fedor ex ore", or "fedor oris"; and is a common condition. A most common disorder in various people is that they have an unpleasant oral odour (Scully and Felix, 2005). It is observed that nearly 8 - 50% of the world population have consistent recurrence of malodour. There are many factors playing vital role in microbial colonisation leading to oral malodour as described in Figure 4. There are previous studies

reporting the effect of honey in reducing oral malodour in patients suffering from oral squamous cell carcinoma (OSCC) (Drain and Fleming, 2015), but less than silver coated bandages (Lund-Nielsen *et al.*, 2011a; 2011b). In particular, Manuka honey is thought to have two pathways for reduction of malodour; (i) it has a bactericidal effect of reducing the bacterial load, and (ii) providing an alternative nutrition to microorganisms, which during metabolism tends to produce lactic acid rather than producing malodour sulphur compounds (Lusby *et al.*, 2002).

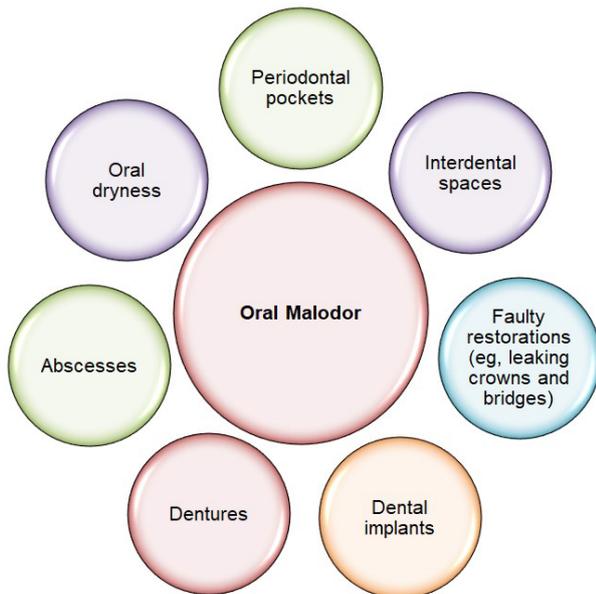


Figure 4. Potential factors for malodour.

#### *Anti-carcinogenic effect of honey*

As oral cancer is one of the most precarious diseases of the oral cavity, it is necessary to evaluate anti-cancer/anti-carcinogenic potential of various available natural products such as honey. As reported by GLOBCAN, lips and oral cavity are the most prevalent sites in head and neck cancer, which observe more than twice the ratio in men than women (Bray *et al.*, 2018). Approximately, there are more than 90% of all cancers in oral cavity, and OSCC is the most prevalent type (Scully and Bagan, 2009). Honey has been reported to have anti-carcinogenic effect on various cultured cell lines (Sela *et al.*, 1998; Molan, 2001; Al-Waili, 2003). A study on anti-cariogenic potential of Tualang honey in various concentrations (1 - 20%) reported that it was effective against OSCC (Ghashm *et al.*, 2010). In another study, it is stated that the cellular death was time- and dose-dependent (Ghashm *et al.*, 2010). Nearly 4% concentration of Tualang honey has demonstrated 50% inhibition in abnormal cell growth; whereas on increasing the concentration to 15%, approximately 80% inhibitory effect was observed (Ghashm *et al.*, 2010). Honey has

also been reported to regulate inflammation, cell cycle, cell growth, and cell proliferation. Furthermore, it also stimulates cellular apoptosis (Abubakar *et al.*, 2012; Ahmed and Othman, 2013; Jaganathan *et al.*, 2015; Ahmed *et al.*, 2018).

#### *Effect of honey in radiation-induced disorders*

Radiation therapy is commonly used for cancer treatment in post-surgery/post-chemotherapy, or used in combination with chemotherapy in order to increase the effectiveness to kill carcinogenic cell line (Sonis, 2013; Sroussi *et al.*, 2017). However, this tends to lead to various side effects which include xerostomia and mucositis, leading to immense pain (Elad *et al.*, 2013; Sonis, 2013). A study reported that patients treated for head and neck cancer with radiation therapy in combination with tropical honey tend to show more than 55% better prevention from mucositis than the control group (Biswal *et al.*, 2003). As honey reduces the prevalence of radiation-induced mucositis, it also reduces the treatment-breaks and further weight loss (Abdulrhman *et al.*, 2012; Maiti *et al.*, 2012; Jayachandran and Balaji, 2012; Samdariya *et al.*, 2015; Co *et al.*, 2016; Jayalekshmi *et al.*, 2016; Kobya Bulut and Güdücü Tüfekci, 2016; Xu *et al.*, 2016; Al Jaouni *et al.*, 2017; Charalambous *et al.*, 2018).

Furthermore, in radiation therapy for head and neck cancer, the salivary secretory units are damaged thus reducing the salivary flow, leading to dryness of mouth/xerostomia (Radvansky *et al.*, 2013). This compromises the lifestyle of an individual by disturbing the taste sensation, speech, swallowing, and digestion of food. Due to the decrease salivary flow, an individual is prone to mucosal infections and rampant caries (Guchelaar *et al.*, 1997). Charalambous *et al.* (2017) compared the effect of saline with thyme honey in patients with radiation-induced xerostomia. They reported that thyme honey is effective in uplifting the overall quality of life, and also reduces pain and dysphagia (Charalambous *et al.*, 2017).

#### *Honey enhances wound healing*

Honey has shown good effects in wound healing as reported by previous studies (Kumar and Jagetia, 1994; 1995). It has also shown excellent effect against open wounds, diabetic wounds, and burns (Cooper, 2016; Saikaly and Khachemoune, 2017). In a pilot study demonstrated by Robson and Cooper (2009), tropical honey application by hydro-fibre rope and non-adhesive foam enhances wound healing without any adverse effects (Robson and Cooper, 2009). Rothmeier *et al.* (2014) demonstrated that patients' undergone surgery for head and neck cancer in post-operative treatment with honey showed wound

healing at a faster pace in comparison to the control group (Rothmeier *et al.*, 2014). Furthermore, studies have reported that Tualang honey when used in patients of post-tonsillectomy, resulted in potent enhancement in wound healing (Mat Lazim *et al.*, 2013). Thus, honey is considered as an efficient agent for wound healing.

## Conclusion

To conclude, honey has countless medicinal benefits against oral diseases such as gingivitis, malodour, plaque, cancer, radiation-dependent xerostomia, and mucositis. Although benefits of honey have been widely reported, further investigations are required to determine the mechanism of honey in modulating the oral diseases.

## References

- Abdulrhman, M., Elbarbary, N. S., Ahmed Amin, D. and Saeid Ebrahim, R. 2012. Honey and a mixture of honey, beeswax, and olive oil-propolis extract in treatment of chemotherapy-induced oral mucositis: a randomized controlled pilot study. *Pediatric Hematology and Oncology* 29(3): 285-292.
- Abubakar, M. B., Abdullah, W. Z., Sulaiman, S. A. and Suen, A. B. 2012. A review of molecular mechanisms of the anti-leukemic effects of phenolic compounds in honey. *International Journal of Molecular Sciences* 13(11): 15054-15073.
- Ahmad, R. S., Hussain, M. B., Saeed, F., Waheed, M. and Tufail, T. 2017. Phytochemistry, metabolism, and ethnomedical scenario of honey: a concurrent review. *International Journal of Food Properties* 20(Suppl. 1): S254-S269.
- Ahmed, S. and Othman, N. H. 2013. Honey as a potential natural anticancer agent: a review of its mechanisms. *Evidence-Based Complementary and Alternative Medicine* 2013: article ID 829070.
- Ahmed, S., Sulaiman, S. A., Baig, A. A., Ibrahim, M., Liaqat, S., Fatima, S., ... and Othman, N. H. 2018. Honey as a potential natural antioxidant medicine: an insight into its molecular mechanisms of action. *Oxidative Medicine and Cellular Longevity* 2018: article ID 8367846.
- Ajibola, A., Chamunorwa, J. P. and Erlwanger, K. H. 2012. Nutraceutical values of natural honey and its contribution to human health and wealth. *Nutrition and Metabolism* 9: article no. 61.
- Al Jaouni, S. K., Al Muhayawi, M. S., Hussein, A., Elfiki, I., Al-Raddadi, R., Al Muhayawi, S. M., ... and Harakeh, S. 2017. Effects of honey on oral mucositis among pediatric cancer patients undergoing chemo/radiotherapy treatment at King Abdulaziz University Hospital in Jeddah, Kingdom of Saudi Arabia. *Evidence-Based Complementary and Alternative Medicine* 2017: article ID 5861024.
- Al-Waili, N. S. 2003. Effects of daily consumption of honey solution on hematological indices and blood levels of minerals and enzymes in normal individuals. *Journal of Medicinal Food* 6(2): 135-40.
- Aruni, A. W., Dou, Y., Mishra, A. and Fletcher, H. M. 2015. The biofilm community - rebels with a cause. *Current Oral Health Reports* 2(1): 48-56.
- Asadi-Pooya, A. A., Pnjehshahin, M. R. and Beheshti, S. 2003. The antimycobacterial effect of honey: an *in vitro* study. *Rivista di Biologia* 96(3): 491-495.
- Atwa, A. D., AbuShahba, R. Y., Mostafa, M. and Hashem, M. I. 2014. Effect of honey in preventing gingivitis and dental caries in patients undergoing orthodontic treatment. *Saudi Dental Journal* 26(3): 108-114.
- Baltas, N., Yildiz, O. and Kolayli, S. 2016. Inhibition properties of propolis extracts to some clinically important enzymes. *Journal of Enzyme Inhibition and Medicinal Chemistry* 31(Suppl. 1): 52-55.
- Bansal, V., Medhi, B. and Pandhi, P. 2005. Honey--a remedy rediscovered and its therapeutic utility. *Kathmandu University Medical Journal* 3(3): 305-309.
- Beena, J. P., Sahoo, P., Konde, S., Raj, N. S., Kumar, N. C. and Agarwal, M. 2018. Manuka honey: a potent cariostatic agent - an *in vitro* study. *International Journal of Clinical Pediatric Dentistry* 11(2): 105-109.
- Biesbrock, A. R., Walters, P. A., Bartizek, R. D., Goyal, C. R. and Qaqish, J. G. 2008. Plaque removal efficacy of an advanced rotation-oscillation power toothbrush versus a new sonic toothbrush. *American Journal of Dentistry* 21(3): 185-188.
- Biswal, B. M., Zakaria, A. and Ahmad, N. M. 2003. Topical application of honey in the management of radiation mucositis: a preliminary study. *Supportive Care in Cancer* 11(4): 242-248.
- Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R. L., Torre, L. A. and Jemal, A. 2018. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA - A Cancer Journal for Clinicians* 68(6): 394-424.

- Charalambous, A., Lambrinou, E., Katodritis, N., Vomvas, D., Raftopoulos, V., Georgiou, M., ... and Charalambous, M. 2017. The effectiveness of thyme honey for the management of treatment-induced xerostomia in head and neck cancer patients: a feasibility randomized control trial. *European Journal of Oncology Nursing* 27: 1-8.
- Charalambous, M., Raftopoulos, V., Paikousis, L., Katodritis, N., Lambrinou, E., Vomvas, D., ... and Charalambous, A. 2018. The effect of the use of thyme honey in minimizing radiation - induced oral mucositis in head and neck cancer patients: a randomized controlled trial. *European Journal of Oncology Nursing* 34: 89-97.
- Co, J. L., Mejia, M. B., Que, J. C. and Dizon, J. M. 2016. Effectiveness of honey on radiation-induced oral mucositis, time to mucositis, weight loss, and treatment interruptions among patients with head and neck malignancies: a meta-analysis and systematic review of literature. *Head Neck* 38(7): 1119-1128.
- Cooper, R. 2016. Honey for wound care in the 21<sup>st</sup> century. *Journal of Wound Care* 25(9): 544-552.
- Drain, J. and Fleming, M. O. 2015. Palliative management of malodorous squamous cell carcinoma of the oral cavity with Manuka honey. *Journal of Wound Ostomy and Continence Nursing* 42(2): 190-192.
- Elad, S., Bowen, J., Zadik, Y., Lalla, R. V. and Mucositis Study Group of the Multinational Association of Supportive Care in Cancer/International Society of Oral Oncology (MASCC/ISOO). 2013. Development of the MASCC/ISOO clinical practice guidelines for mucositis: considerations underlying the process. *Supportive Care in Cancer* 21(1): 309-312.
- Emsen, I. M. 2007. A different and safe method of split thickness skin graft fixation: medical honey application. *Burns* 33(6): 782-787.
- Eteraf-Oskouei, T. and Najafi, M. 2013. Traditional and modern uses of natural honey in human diseases: a review. *Iranian Journal of Basic Medical Sciences* 16(6): 731-742.
- Ezz El-Arab, A. M., Girgis, S. M., Hegazy, E. M. and Abd El-Khalek, A. B. 2006. Effect of dietary honey on intestinal microflora and toxicity of mycotoxins in mice. *BMC Complementary and Alternative Medicine* 6: article no. 6.
- Fehrenbach, M. and Popowics, T. 2015. *Illustrated dental embryology, histology, and anatomy*. 4<sup>th</sup> ed. United States: Saunders.
- Gašić, U. M., Milojković-Opsenica, D. M. and Tešić, Ž. L. 2017. Polyphenols as possible markers of botanical origin of honey. *Journal of AOAC International* 100(4): 852-861.
- Ghashm, A. A., Othman, N. H., Khattak, M. N., Ismail, N. M. and Saini, R. 2010. Antiproliferative effect of Tualang honey on oral squamous cell carcinoma and osteosarcoma cell lines. *BMC Complementary and Alternative Medicine* 10: article no. 49.
- Guchelaar, H. J., Vermes, A. and Meerwaldt, J. H. 1997. Radiation-induced xerostomia: pathophysiology, clinical course and supportive treatment. *Supportive Care in Cancer* 5(4): 281-288.
- Henriques, A. F., Jenkins, R. E., Burton, N. F. and Cooper, R. A. 2011. The effect of Manuka honey on the structure of *Pseudomonas aeruginosa*. *European Journal of Clinical Microbiology and Infectious Diseases* 30(2): 167-171.
- Ho, H. P. and Niederman, R. 1997. Effectiveness of the Sonicare sonic toothbrush on reduction of plaque, gingivitis, probing pocket depth and subgingival bacteria in adolescent orthodontic patients. *The Journal of Clinical Dentistry* 8(1): 15-19.
- Jaganathan, S. K., Balaji, A., Vellayappan, M. V., Asokan, M. K., Subramanian, A. P., John, A. A., ... and Marvibaigi, M. A. 2015. A review on antiproliferative and apoptotic activities of natural honey. *Anti-Cancer Agents in Medicinal Chemistry* 15(1): 48-56.
- Jayachandran, S. and Balaji, N. 2012. Evaluating the effectiveness of topical application of natural honey and benzydamine hydrochloride in the management of radiation mucositis. *Indian Journal of Palliative Care* 18(3): 190-195.
- Jayalekshmi, J. L., Lakshmi, R. and Mukerji, A. 2016. Honey on oral mucositis: a randomized controlled trial. *Gulf Journal of Oncology* 1(20): 30-37.
- Jin, L. J., Lamster, I. B., Greenspan, J. S., Pitts, N. B., Scully, C. and Warnakulasuriya, S. 2016. Global burden of oral diseases: emerging concepts, management and interplay with systemic health. *Oral Diseases* 22(7): 609-619.
- Khan, S. U., Anjum, S. I., Rahman, K., Ansari, M. J., Khan, W. U., Kamal, S., ... and Khan, H. U. 2018. Honey: single food stuff comprises many drugs. *Saudi Journal of Biological Sciences* 25(2): 320-325.
- Koby Bulut, H. and Güdücü Tüfekci, F. 2016. Honey prevents oral mucositis in children undergoing chemotherapy: a quasi-experimental study with a control group. *Complementary Therapies in Medicine* 29: 132-140.

- Kolayli, S., Sahin, H., Can, Z., Yildiz, O. and Sahin, K. 2016. Honey shows potent inhibitory activity against the bovine testes hyaluronidase. *Journal of Enzyme Inhibition and Medicinal Chemistry* 31(4): 599-602.
- Kumar, P. and Jagetia, G. C. 1994. A review of triage and management of burns victims following a nuclear disaster. *Burns* 20(5): 397-402.
- Kumar, P. and Jagetia, G. C. 1995. Modulation of wound healing in Swiss albino mice by different doses of gamma radiation. *Burns* 21(3): 163-165.
- Lund-Nielsen, B., Adamsen, L., Gottrup, F., Rørth, M., Tolver, A. and Kolmos, H. J. 2011a. Qualitative bacteriology in malignant wounds--a prospective, randomized, clinical study to compare the effect of honey and silver dressings. *Ostomy/Wound Manage* 57(7): 28-36.
- Lund-Nielsen, B., Adamsen, L., Kolmos, H. J., Rørth, M., Tolver, A. and Gottrup, F. 2011b. The effect of honey-coated bandages compared with silver-coated bandages on treatment of malignant wounds - a randomized study. *Wound Repair and Regeneration* 19(6): 664-670.
- Lusby, P. E., Coombes, A. and Wilkinson, J. M. 2002. Honey: a potent agent for wound healing? *Journal of Wound, Ostomy, and Continence Nursing* 29(6): 295-300.
- Mager, D. L., Ximenez-Fyvie, L. A., Haffajee, A. D. and Socransky, S. S. 2003. Distribution of selected bacterial species on intraoral surfaces. *Journal of Clinical Periodontology* 30(7): 644-654.
- Maiti, P. K., Ray, A., Mitra, T. N., Jana, U., Bhattacharya, J. and Ganguly, S. 2012. The effect of honey on mucositis induced by chemoradiation in head and neck cancer. *Journal of the Indian Medical Association* 110(7): 453-456.
- Mandal, S., DebMandal, M., Pal, N. K. and Saha, K. 2010. Antibacterial activity of honey against clinical isolates of *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella enterica* serovar Typhi. *Asian Pacific Journal of Tropical Medicine* 3(12): 961-964.
- Marsh, P. D. and Martin, M. V. 2009. The mouth as a microbial habitat. In Marsh, P., Lewis, M., Williams, D. and Martin, M. (eds). *Oral Microbiology* (5<sup>th</sup> ed), p. 8-23. United Kingdom: Churchill Livingstone.
- Mat Lazim, N., Abdullah, B. and Salim, R. 2013. The effect of Tualang honey in enhancing post tonsillectomy healing process. An open labelled prospective clinical trial. *International Journal of Pediatric Otorhinolaryngology* 77(4): 457-461.
- Molan, P. C. 2001. The potential of honey to promote oral wellness. *General Dentistry* 49(6): 584-589.
- Moritis, K., Delaurenti, M., Johnson, M. R., Berg, J. and Boghosian, A. A. 2002. Comparison of the Sonicare Elite and a manual toothbrush in the evaluation of plaque reduction. *American Journal of Dentistry* 15: 23B-25B.
- Nanci, A. 2014. *Ten Cate's oral histology: development, structure and function*. 8<sup>th</sup> ed. United States: Elsevier Health Sciences.
- Nayak, P. A., Nayak, U. A. and Mythili, R. 2010. Effect of Manuka honey, chlorhexidine gluconate and xylitol on the clinical levels of dental plaque. *Contemporary Clinical Dentistry* 1(4): 214-217.
- Nicolson, S. W. and Human, H. 2008. Bees get a head start on honey production. *Biology Letters* 4(3): 299-301.
- Radvansky, L. J., Pace, M. B. and Siddiqui, A. 2013. Prevention and management of radiation-induced dermatitis, mucositis, and xerostomia. *American Journal of Health-System Pharmacy* 70(12): 1025-1032.
- Robson, V. and Cooper, R. 2009. Using leptospermum honey to manage wounds impaired by radiotherapy: a case series. *Ostomy/Wound Management* 55(1): 38-47.
- Rothmeier, N., Abu-Jawad, J., Arnolds, J., Arweiler-Harbeck, D., Dominas, N., Stein, R., ... and Mattheis, S. 2014. The treatment of chronic wounds in the head and neck area after radiotherapy with medical honey. *Laryngo-Rhino-Otologie* 93(9): 612-618.
- Saikaly, S. K. and Khachemoune, A. 2017. Honey and wound healing: an update. *American Journal of Clinical Dermatology* 18(2): 237-251.
- Samaranayake, L. P. 2002. *Essential microbiology for dentistry*. 2<sup>nd</sup> ed. United Kingdom: Churchill Livingstone.
- Samdariya, S., Lewis, S., Kauser, H., Ahmed, I. and Kumar, D. A. 2015. A randomized controlled trial evaluating the role of honey in reducing pain due to radiation induced mucositis in head and neck cancer patients. *Indian Journal of Palliative Care* 21(3): 268-273.
- Scannapieco, F. A. 2013. The oral microbiome: its role in health and in oral and systemic infections. *Clinical Microbiology Newsletter* 35(20): 163-169.
- Scully, C. and Bagan, J. 2009. Oral squamous cell carcinoma: overview of current understanding of aetiopathogenesis and clinical implications. *Oral Diseases* 15(6): 388-399.
- Scully, C. and Felix, D. H. 2005. *Oral medicine--up*

- date for the dental practitioner: oral malodour. *British Dental Journal* 199(8): 498-500.
- Sela, M. O., Shapira, L., Grizim, I., Lewinstein, I., Steinberg, D., Gedalia, I. and Grobler, S. R. 1998. Effects of honey consumption on enamel microhardness in normal versus xerostomic patients. *Journal of Oral Rehabilitation* 25(8): 630-634.
- Singhal, R., Siddibhavi, M., Sankeshwari, R., Patil, P., Jalihal, S. and Ankola, A. 2018. Effectiveness of three mouthwashes - Manuka honey, raw honey, and chlorhexidine on plaque and gingival scores of 12-15-year-old school children: a randomized controlled field trial. *Journal of Indian Society of Periodontology* 22(1): 34-39.
- Sonis, S. T. 2013. Oral mucositis in head and neck cancer: risk, biology, and management. United States: 2013 ASCO Annual Meeting.
- Sroussi, H. Y., Epstein, J. B., Bensadoun, R. J., Saunders, D. P., Lalla, R. V., Migliorati, C. A., ... and Zumsteg, Z. S. 2017. Common oral complications of head and neck cancer radiation therapy: mucositis, infections, saliva change, fibrosis, sensory dysfunctions, dental caries, periodontal disease, and osteoradionecrosis. *Cancer Medicine* 6(12): 2918-2931.
- Tritten, C. B. and Armitage, G. C. 1996. Comparison of a sonic and a manual toothbrush for efficacy in supragingival plaque removal and reduction of gingivitis. *Journal of Clinical Periodontology* 23(7): 641-648.
- Xu, J. L., Xia, R., Sun, Z. H., Sun, L., Min, X., Liu, C., ... and Zhu, Y. M. 2016. Effects of honey use on the management of radio/chemotherapy-induced mucositis: a meta-analysis of randomized controlled trials. *International Journal of Oral and Maxillofacial Surgery* 45(12): 1618-1625.
- Zhu, R., Lv, H., Liu, T., Yang, Y., Wu, J. and Yan, S. 2016. Feeding kinematics and nectar intake of the honeybee tongue. *Journal of Insect Behavior* 29(3): 325-339.