



Testimony for Veterinary Apitherapy

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Abstract

Nowadays by the indiscriminate use of antibiotics, multi-drug resistant pathogens (MDR) developed and spread, so searching for effective natural antimicrobials is of global concern. Apitherapy possessing various therapeutic activities (antimicrobial [1,2], anti-inflammatory [3-5], antioxidant [6-9], anti-proliferative [10], immunomodulator [11] ameliorative [12,13] or wound healing factor [14,15]) proved to be a suitable tool to get the target since it is very safe, highly effective, easily applicable and extremely economic. The subject is of interesting concept for the apitherapy research team affiliating to Animal Health Research Institute, Assiut and Faculty of Veterinary Medicine, Assiut University, Egypt. The team produced many research works (no 12) which were tabulated in tables 1(*in vitro* antimicrobial activity), 2(antioxidant, immunomodulative and toxicity ameliorative factors) and 3 (applied honey apitherapy in lactating dairy cows) dealt with different veterinary apitherapeutic applications of different apiproductions; honey, propolis and bee venom.

Keywords: Apitherapy; Fennel; Antimicrobial; Antioxidant; Immune boosting; Wound healing; Methoxychlor toxicity

Abbreviations: MDR: Multi Drug Resistant; EEP: Ethanolic Extract of Propolis; MRSA: Methicillin Resistant Staphylococcus Aureus; TBC: Total Bacterial Count; EOs: Essential Oils; SLN: Solid Lipid Nanoparticle; SOD: Superoxide Dismutase; MGX: Methylglyoxal

Introduction

Apitherapeutic management is reborn in the modern medicine, established documentary and be advised by physicians to wide variety of patients complaining different health problems. The concept of veterinary apitherapy must be of great concern as it highly safe of animal products extremely effective and greatly economic. As mentioned above, apitherapy has wide spectrum therapeutic activities with variable varieties of

mechanism of action, of among them, our referred research works dealt with.

Antimicrobial Activity (*In vitro* assay)

Antibiotic resistance of bacteria is on the rise, thus the discovery of alternative therapeutic agents is urgently needed [2]. Since the antimicrobial honey activity proved to have wide varied potencies depending on botanical, geographical and seasonal conditions [2,16] leading to differences in antimicrobial potency more than 100-fold in-between different honeys [2,17], the *in vitro* assessment before any honey therapeutic use is required. Fennel honey among Egyptian honey batches has highly antimicrobial activity compared with prickly, sesame and cotton honey [18] or trefoil, marjoram and cotton honey [19] showing synergistic action when adding ethanolic

extract of propolis (EEP) [14,19] even only 5% of both [2]. Honey EEP synergy is proved against different *Staph* species [19,20] or even stubborn methicillin resistant (MRSA) [2] strains biofilm producing with much antibacterial resistance either from bovine or human sources [2]. The antimicrobial activity of crude unprocessed honey is maximized when be diluted and diminished when be autoclaved or heated [21], where this potency is highly complex due to the involvement and interaction of multiple compounds in honey [22]. Egyptian fennel honey inhibits MRSA at 7% [2] and Gram's negative (*proteus, pseudomonas, klebsiella*) at 25% [18]. Despite, EEP has promising activity against *Klebsiella pneumonia* [23], *Strept mutans* [24], *E. coli* [21] particularly in high concentration [24] but much lower antimicrobial potency than honey [2]. Bee venom apitherapeutic application (Bee sting) might provide antimicrobial activity [4,25].

The in vitro honey antibacterial activities depend on physicochemical properties (osmotic pressure, low pH of 3 to 4.5 and non-peroxide factors as polyphenols [1,26], phenolic acids as caffeic and flavonoids mainly chrysin [8,27]) as well as peroxide effects due to H₂O₂ level in honey which is involved in oxidative damage causing bacterial growth inhibition by DNA degradation and modulated by other honey components [26]. Although H₂O₂ is an important factor in the bacterial growth inhibition, poly-phenolic compounds and their interaction with H₂O₂ are the key factors responsible for honey high antibacterial activity [28]. Other micro components honey glycoprotein fractions as antimicrobial peptide bee defensin-1 [11,22] exhibited strong growth inhibition by binding and agglutination of bacterial cells or membrane permeabilization of bacterial cells [29,30]. Moreover, the presence of methylglyoxal (MGX) exhibited in manuka

honey may modify some honey proteinaceous compounds and therefore affect the glucosidase activity [31] sharing in antimicrobial action. *Staph aureus* is a pathogen highly sensitive to the antibacterial action of honey [32] even when be MRSA [33] producing biofilm [2] with additional different antibacterial mechanisms; inhibition of cell division, collapsing microbial cytoplasm cell membranes and cell walls, inhibition of bacterial motility, enzyme inactivation, bacteriolysis, and protein synthesis inhibition [34]. Inhibition of biofilm formation by reducing the expression of 2-fibronectin binding proteins by honey MGX [35] which is abundant component in manuka honey (the highest antimicrobial antioxidant)[36].

Bioactivities of EEP where the major constituents exhibited polyphenols, aromatic acids, terpenes and flavonoids [23] are not directly related to its concentration, but a synergistic activity [37] and interaction between these various active ingredients is believed to be a main factor in achieving the complex antimicrobial activity of propolis [23,38]. Other micro bioactive components; artemillin C [39] and the flavonoid formononetin [40], while polyphenols interacts with many microbial proteins by forming hydrogen and ionic bonds, thus altering their three-dimensional (3D) structure of a protein and as a consequence their functionality [23].

Bee venom has antimicrobial activity where melittin (cationic peptides - AMPs), the major active peptide of bee venom [4,25,41] has antimicrobial activity affecting bacterial cell wall (outer membrane proteins and lipopolysaccharides) [25,42] and colistin rather than its antibiofilm activity [43] (Table 1).

Bact. Spp.	Source	Honey	Method	MIC	MBC	Reference
<i>S. aureus</i>	Bovine purulent endometritis	cotton	Broth dilution in tubes	10%	UD	Abdul-Hafeez et al. 2001 [44]
<i>S. intermedius</i>				20%		
<i>S. epidermidis</i>						
<i>S. saprophyticus</i>						
<i>Strept. agalactiae</i>	Bovine subclinical mastitis	Fennel*	Broth dilution in tubes	12.5%	25%	Ali et al. 2005 [18]
<i>S. aureus</i>				25%	UD	
<i>Ps. auroginosa</i>						
<i>Proteus spp.</i>						
<i>Kl. pneumoniae</i>						
<i>S. aureus</i>	Bovine subclinical mastitis	Fennel honey with 10% propolis extract**	Broth dilution in tubes	8%	15%	Aamer et al. 2014 [19]
<i>S. intermedius</i>				7.5%	13%	
<i>S. epidermidis</i>				15%	28%	
<i>S. saprophyticus</i>				27%	42%	

MRSA	Dairy food	Fennel honey	Agar dilution	7%	Hamouda et al. 2018 [2]
	Meat			10.6%	
	Throat (dairy food workers)			9.3%	
	Fingernail (dairy food workers)			8.2%	
	Dairy food	EEP		14%	
	Meat			15%	
	Throat (dairy food workers)			12%	
	Fingernail (dairy food workers)			16%	
	Dairy food	5% Fennel honey*** with 5% EEP		7.1%	
	Meat			8%	
	Throat (dairy food workers)			8.2%	
	Fingernail (dairy food workers)			7.7%	

Table 1: *In vitro* studies of honey antimicrobial activity against clinical different MDR bacterial spp.

- All isolated bacterial species were tested for antibiotic sensitivity (disc diffusion method) showing to be as MDR strains, and then be tested against honey.
- *Fennel honey showed the least MIC than that of Prickly, Sesame and cotton honey batches.
- ** Fennel with 10% EEP showed the least MIC than two different pure fennel, two different trefoil, and marjoram, cotton honey batches.
- *** Fennel with 5% EEP (synergy) showed the least MIC than pure Fennel honey or pure EEP.
- UD: undone.

Antioxidant Activity

The imbalance between oxidative stress and antioxidant scavengers leads to damage of important biomolecules resulting in malonaldehyde (MDA) production [45] and the body has a defense mechanism against its harmful effects through neutralizing the free radicals by means of either endogenous enzymatic glutathione peroxidase (GPX) and superoxide dismutase (SOD) [46] or non-enzymatic e.g. catalase, alkaloids, ascorbate [47], flavonoids [8,48], selenium [46], vit. C and vit. E [49]. Honey antioxidant activity exhibited by different bioactive micro components [50] such as flavonoids [8,9], phenolic compounds [51], chrysin [52] and amino acids [53] but the main antioxidants are considered to be the polyphenols [54]. Different antinociceptive effects of different fractions from Chinese EEP mainly chrysin [55], but honey [6] or propolis [55] chrysin as a polyphenolic compound or galanin [56]- which is an abundant component in honey - has anti-inflammatory [3] and antioxidant properties [57] enhancing protein stability [52,58], solid lipid nanoparticle (SLN) synthesis avoiding proteolytic degradation [52] resulting antiproliferating [6,59] action. This activity is achieved on honey oral [47,60] or intravenous(I/V) [7,10] administration as increase GPX & SOD and decrease the free radical

metabolites malonaldehyde (MDA) due to inhibition of the pro-inflammatory cytokines(TNF- α , IL-1 β and IL-6 [60]. Although I/V honey apitherapy proved to acquire all targeted advantages, it is not advisable avoiding risky factors [7] since daily oral administration gives all positive results [61,62] comparing with intra-peritoneal route where regular consumption of honey is appraised [61].

Boosting Immunity

There is an important correlation between high antioxidant and antimicrobial activity [11], moreover, the antioxidant components present in honey [61-63] and EEP [61,64] play a great role in their immunomodulation properties. So, the above mentioned bioactive components at least have all antimicrobial, antioxidant and immunological boosting factors. Honey increases T and B lymphocytes [62,65,66] as a result of its protection of lymphocyte DNA from oxidative damage [67], while manuka honey protect DNA of not only lymphocytes but also whole blood cells from oxidative damage [68]. It is interesting that muscular exercise with honey oral supplementation reveals an increase in T lymphocyte function [69]. Honey and EEP increase other blood cellular immunological elements; neutrophils [62] and

monocytes [7,61,62] rather than serum globulin [61,62]. Moreover, apitherapeutic administration of honey [70] and EEP [64] activate lymphocytic function resulting in proliferation of lymphatic follicles [61]. The immune system response to different stimuli depends on the secretion of different metabolites from macrophages [4] and its phagocytosis might be activated with honey [71] or EEP [7,72,73] administration. Not only honey and propolis apitherapy improves the immune status, but also bee venom boost cellular immunity [61] but less activity and honey bee pollen significantly increases the globulins level and phagocytic activity rather than neutrophils, monocytes and lymphocytes percentages [61,74]. Bee venom melittin enhances the release of tumour necrosis factor- α (TNF- α), Interleukin (IL-1 β , IL-6, and IL-10) cytokines [4] from macrophages affecting the immune status positively.

Amelioration Effect of EEP Against Induced Methoxychlor (MXC) Toxicity

Although MXC (organochlorine pesticide) is banned by 2004 since failure of registration with the Environmental Protection Agency [75], it is used and presented residues contaminating lakes [12] or river fish [13], then animal foodstuffs. Its toxicity affects liver [76], testis, ovary [77], kidneys [76], spleen, blood vessels, pituitary, adrenals and mammary glands [78]. Additionally to the above bioactive properties of EEP, it is proved that having protection

properties (amelioration) against MXC [79], methotrexate [80], benzopyrene [81] or chlorpyrifos [79,82] induced toxicity. Due to EEP immunomodulation potency by different mechanisms of micro-components (mainly flavonoids and phenolic acids), it's anti-oxidative and anti-inflammatory [5] properties resulted in such different amelioration effects and chrysin [83] which inhibits induced kidney fibrosis [84]. Moreover, lactating animals excrete MXC in milk [85] with potential human health hazard. Subsequently, animals contract MXC toxicity result several toxicological implications as ovarian toxicity [77], where it causes impairment of ovarian follicular development and other ovarian function [77,86] leading to reproductive tract malformations in the male offspring [87]. MXC hepto-toxicity results in significant reduction in total serum protein rather than marked elevation in hepatic marker enzymes (ALT, AST & ALP) [76] as well as changes in inter and intra cellular signaling [88]. Histopathologically, there is changes in hepatocytes [76,89] owing to induction changes in mRNA abundance of genes in the liver and testes [90], where alterations involved in regulations of gene expression, tissue development, function and homeostasis, could also contribute to transgenerational epigenetic effects of endocrine disruptors [88]. MXC affect kidneys causing toxic nephrosis [76] and dysfunction through inhibition of renal tubular cell viability and induction of cell apoptosis via mitochondrial pathways [91] (Table 2).

Studied parameter	Animal	Apiproduct	Mode of application	Conclusions	Reference
Antioxidant activity and immunomodulation	Goats	fennel honey	Rapidly intravenously infused 20% honey solution (70-80 drops/min) in normal saline solution	In 75% of infused goats: \uparrow the activity of antioxidants (GPX & SOD) and \downarrow free radicals metabolites, improving haemideces (\uparrow WBCs, \uparrow lymphocytes, \uparrow monocytes and \uparrow serum globulins). While the rest 25% had anaphylactic shock and died.	Abdel-Mooty et al. 2018 [7]
Boosting immunity prior experimental induced infection	Sprague Dawley rats	fennel honey	Oral & intraperitoneal 10% honey solution administration for 60 days	All were immunized where oral honey administration showed the highest immunization rate	Sayed et al. 2009 [61].
		EEP	Oral & intraperitoneal administration of aqueous(AEP) & ethanolic extract(EEP) for 60 days		
		Bee venom	Single bee sting for 5		

		(bee sting)	successive times		
Ameliorative effects against MXC toxicity	Sprague Dawley rats	EEP	Orally EEP (200 mg/L, drinking water) for 12 months	propolis protcted MXC-induced hepato renal toxicity	Neveen El Nesr et al. 2013 [76]
		EEP	Orally EEP (200 mg/L, drinking water) for 10 months	propolis decreased MXC-induced ovarian toxicity	Eman El Sharkawy et al. 2014 [77]

Table 2: Apitherapy in normal healthy animals as antioxidant, immunomodulative and toxicity ameliorative factors.

Honey apitherapy in lactating dairy cows

Among different lactating Holstein dairy farms, four papers of the referred works [44,92-94] applied honey apitherapy were dealt with three dairy farm problems.

Bovine endometritis

Well managed and profitable dairy farming requires animal with good reproductive performance [95], but uterine postpartum infection with MDR pathogens which is so common threaten fertility [96] causing major cause of economic loss [97]. Bovine endometritis and prolonged luteal phase leading to repeat breeder (infertility complain) is significantly increased in cows with persistent infections [96]. Alternative intrauterine(I/U) infusion was widely documented and tried; with own affected cow hyper immune serum [98], polymorph nuclear leucocytes, exotoxine of *E. coli* lipopolysaccharides [99], multiherbal extract [100], chitosan [101], low dilutions of H₂O₂ [102] silver nanoparticles [103], *Momordica charantia* [104] garlic, neem, ashwagandha, and turmeric [105] or tulsi and giloy [106] herbal EOs. Even lactic acid probiotic *Pediococcus acidilactici* and *Lactobacillus reuteri* [107] therapy was tried concluded that treatment remains to be confirmed [102] as it may increase the pregnancy rate in cows [104].

Bovine honey I/U infusion have wonderful results [44] since the study conducted 24 lactating cows suffering from exudative purulent endometritis with repeat breeder complain. Despite the treatment success is judged by total conception rate not only clearance of clinical signs, it was 75% (83.8 % in cows did not accept any antibiotics & 70 % in cows previously antibiotic treated) just post three I/U infusions of 100 ml pure undiluted honey day by day. In mare indometritis, MDR infection appear to be more difficult since it is commonly associated with biofilm [108], so biofilm was targeted alternatively *in vitro* [109] and *in vivo* with N-acetylcysteine, H₂O₂, ozone and hypochlorous acid giving no reducing in biofilm [108]. Authors recommended to use these non-antibiotics combined with antibiotic infusion where must be administered with separate syringes [108]. By 70% honey I/U infusion in mares

[110], positive results to both targets (antimicrobial and anti-biofilm- as mentioned above) against endometritis pathogens but not as in bovine, where treatment success is judged by endometrium ultrasound and cytological examinations showing clinically clearance of endometritis, but fertility was not improved.

Bovine subclinical mastitis

Mastitis imposes considerable economic losses on the dairy industry all over the world [111], where it is one of the most vital noteworthy monetary risks to dairy ranchers and affects reproductive performance in dairy cattle [112]. The overwhelming usage of antibiotics and prolonged infection treatment has led to emergence of MDR pathogens [103]. The emergence of antibiotic resistant microorganisms is a great public health concern and has triggered an urgent need to develop alternative antibiotics [113]. Based on the antibacterial properties of agents from plants, the antimicrobial action of essential oils (EOs) of medicinal plants and its feasibility to be intramammary infused it is recommended [114], but as the mammary gland is very susceptible tissue to irritation, any intramammary infusions should be non-irritating [115]. Following the *in vitro* testing, clinical trials intramammary infusion (I/Mm) of any alternative medicinal product must be warranted to determine safety and possible withdrawal time in milk before its recommendation for use [116]. The *in vitro* assessment of EOs; *Origanum vulgare* [41], *Thymus vulgaris* and *Lavandula angustifolia* [117], fruit guttiferone-A and 7-epiclusianone [118], onion and black cumin [119] or chitosan hydrogel [120] against bovine mastitis pathogens and *Salvia officinalis* [116] against ewe subclinical mastitis pathogens was documented. EOs I/Mm application [116,117] concluded variable results away from its *in vitro* assessment as external massage with EO ointment had activity more than that of I/Mm [117] or I/Mm had significant results when be combined with antibiotics [116] even chitosan hydrogel is recommended only for uninfected cows as it is not a complete replacement for antibiotic dry cow therapy [120]. Despite of the positive *in vitro* antimicrobial potency of probiotic lactic acid bacteria due to produced bacteriocin and elicit substantial innate immunity [121],

the I/Mm infusion of *Lactobacillus lactis* [121-123], *Weissella confuse* [124,125] or *Lactobacillus acidophilus* [126] concluded no increase in intramammary cure rate [126] where *S. aureus* infections did not improve, and coagulase negative staphylococcal infections tended to relapse [123] with abnormal milk secretions and udder inflammation. Thus its I/Mm should not be adopted [124], but I/Mm of 10% solution of thymus and lavender Eos [117] showed synergistic action which the only study recommended EOs I/Mm infusion.

Otherwise, the *in vitro* testing of honey against pathogens of bovine [2,18,19] and ovine mastitis [119,127,128] encouraged its I/Mm infusion where by 20% fennel honey followed by 30% then 40% finally 50% (the *in vitro* MIC) for three successive doses [92] concluded decline in total bacterial count (TBC) and highly significant increase in milk yield. But regardless to the *in vitro* MIC concerning boosting immunity [61], only 10% fennel honey infusion day by day for three doses guarded by antihistaminic drug significantly decreases milk TBC, increase milk yield and improves blood immunological parameters [93]. Subsequently, I/Mm honey infusion is the only successful trend among alternative medicinal approach with unique drawback since extreme CMT positive results [92,93] owing to the highly increased lymphocytes and total leucocytes post honey administration [61,62,65,66,74]. Moreover, milk cytology could be used instead of CMT during and after treatment with honey [93]. Beyond mastitis negative impact on milk yield and milk components, it has a detrimental effect on reproductive

performance in dairy cows [112,129] rather than the mastitis following exudative metritis resulting in mastitis ascending infection.

Bovine claw affections

Topical honey application has a beneficial effect on the healing of cutaneous wounds [130], ulcers [131] or infected chronic wounds showing synergism with *Nigilla sativa* EO [132]. There is good evidence for honey also having bioactivities that stimulate the immune response promoting tissue growth and wound repair, moreover suppress inflammation [133]. Twenty lactating cows suffering from claw lesions either digital dermatitis or interdigital necrobacillosis (infected wound in highly infected media) showing sever lameness were divided to equal four groups of five cows of each. Three groups were treated with medicinal plant extract of *Thymus vulgaris*, *Matricaria chamomilla* and *Origanum vulgare* (as lotion and ointment) with the obtained *in vitro* MIC value against the isolated bacteria. The rest group was dressed only with undiluted honey as honey used in wound care can withstand dilution with substantial amounts of wound exudate maintaining enough activity to inhibit the growth of bacteria [133] accelerating healing process [15]. All groups had different degrees of cure post 30 days but honey group was by 14 days with complete healing [95] concluded that honey is the most effective valuable economic alternative tool than herbal EOs for its healing superiority and application feasibility (Table 3).

Bovine affection	Mode of application	Conclusions	Reference
Purulent endometritis (with repeat breeder)	I/U infusion 00ml honey day by day three successive doses	75% of treated cows got conception	Abdul-Hafeez et al. 2001[44]
Subclinical mastitis	I/Mm infusion of 10ml of 50% fennel honey day by day three successive doses	Milk yield increased significantly	Abdul-Hafeez et al. 2005 [92]
	I/Mm infusion of 10ml 10% fennel honey day by day three successive doses guarded by antihistaminic administration	Milk yield increased significantly	Nahed Wahba et al. 2011 [93]
Surgical claw affections(digital dermatitis and inter digital necrobacillosis)	Pure honey* bandage for 5 consecutive days; 2 days without management; then once daily for other 3 days only up to 14 days.	Complete healing repair and hair developed by 14 days	Ali et al 2017 [94]

Table 3: Application of honey apitherapy in lactating dairy cows.

I/U : intrauterine I/Mm : intramammary

Honey*: showed healing manifestations earlier than other medical herbal (*T. vulgaris*, *O. vulgare* and *M.chamomilla*) lotion and ointments.

Conclusion

Conclusion basing on the former justifications of the wide spectrum antimicrobial efficacy and promoting wound healing as well as tissue growth, honey apitherapy is advisable to be used:

a. Undiluted in cases of direct exposure with the pathogen even MDR either septic wounds & purulent metritis or food additive as a preservative especially those of dairy sources acceptable to be sweetened.

In cases of boosting immunity of healthy non affected animals or subclinical mastitis, 10% honey solution would be enough fully effective.

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