



## Animal Based Bioactives for Health and Wellness

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### Abstract

Bioactive compounds are important constituents of the food that provide health benefits beyond basic nutrition. The animal products contain health promoting substances possessing antioxidant, antithrombotic, anti-inflammatory and anti-carcinogenic properties. In the last two decades, there is enormous increase in the production and consumption of bioactive foods. Food items from animal source include milk, meat, egg and honey. Milk furnishes a wide range of bioactivities that protect infants and adults against illness. The milk bioactive components comprise of specific proteins, antibacterial peptides, lipids and oligosaccharides that are effective in gastrointestinal and immunological development and also improve the probiotic action. On the other hand, meat is a source of endogenous antioxidants such as coenzyme Q10, glutathione, lipoic acid etc and other bioactive substances like carnitine, carnosine, conjugated linoleic acid and essential omega-3 polyunsaturated fats. Some of these ingredients are essential to cellular energy production and to improve the physiological functions of the human body. Eggs are associated with bioactive constituents containing choline, phospholipids, carotenoids e.g. lutein and zeaxanthin and proteins. In addition, antioxidants present in egg yolk prevent age-related macular degeneration. Honey act as a natural therapeutic agent consists of phenolic compounds such as flavonoids and phenolic acids have shown the antimicrobial, antiviral, antifungal, anticancer and anti-diabetic activity. The food technologists have adopted different strategies to modify the concentration of healthy compounds in animal based products to produce safe and healthier functional food products. Hence, animal based bioactives are potentially involved as protective compounds for a number of chronic diseases and can be used as good health food.

**Keywords:** Animal Bioactives; Milk Bioactives; Meat and Meat Products; Egg; Honey

In recent years, health and wellbeing have drawn a lot of attention of consumers. The growing consciousness about the life expectancy, the demand for value added food products is increasing tremendously. These products are known as functional food or designer food that possess various bioactive components providing health benefits beyond basic nutrition. According to, The European Commission's Concerted Action on Functional Food Science in Europe (FuFoSE), functional food is a food product which, together with the basic nutrients imparts beneficial health effects to one or more system of the human organism, thus maintain the general and physical conditions and decrease the risk associated with the development of diseases [1]. The functional food involves reduced fat, sugar or salt, while fortified with minerals and vitamins. The various bioactive compounds present in functional foods are phytochemicals, probiotic bacteria, polyunsaturated fatty acids, etc. These components endow preventive and therapeutic properties for human diseases, acts as

substrates for biomolecule and bio-structure synthesis, modulate bio-system function, prevent against microbes, carrier for drugs, enzymes, and nutrients and so on. According to the Zion market research report, the global market of functional food ingredients or bioactive components were valued around 64,871 million USD in 2018 and is expected to reach approximately 99,975 million USD by 2025, at a CAGR of around 6.74% between 2019 and 2025 [2]. These bioactive components are present either in natural or synthetic form. The major natural source of bioactive components involves plants, animal and microbes. Although a lot of secondary metabolites are present in plant based products but still there are many others bioactive components obtained from animal source. Animal based bioactive plays an important role in human body other than those extracted from plants. They can be easily digested, maintain body function and protect from external and internal stresses. In comparison to plant based food, animal source foods have also made a significant contribution to human health by providing essential nutrients. In addition to quantity, animal based food possess' high quality nutrients that are absorbed readily. It

consists of dense energy, high-quality and readily digested protein with full complement of essential amino acids and micronutrients (Iron, zinc, and vitamin A, vitamin B<sub>12</sub> from meat and riboflavin and calcium from milk). Livestock contributing to the diet in one or the other form include cattle, sheep, goats, pigs, chickens, honey bees, etc. Though animal based foods is the matter of debate due to high total energy content (in kilojoules) and saturated fat. In spite of the infancy in functional food field, several *in vitro* and *in vivo* studies have provided some scientific evidence about the health benefits provided by animal based bioactive including calcium, probiotics, casein and whey proteins and their derived peptides,

conjugated linoleic acid from dairy products; conjugated linoleic acid, conditionally-essential nutrients L-carnitine, coenzyme Q10,  $\alpha$ -lipoic acid, choline and taurine are widely diffused in beef and lamb meat and sphingolipids, from eggs. The amount of various bioactive components present in animal products is enlisted in Table 1. This paper reviews the literature with major consideration on animal food components that are associated with human physiological benefits. The knowledge related to this new topic will help veterinarians and other animal and food scientists to optimize public health, through healthier food products, by improving animal nutrition and food processing.

| Animal source  | Bioactive compound       | Amount present   | Health benefits  | References |
|----------------|--------------------------|--|--|------------|
| Dairy products | Casein                   | 26 g/L in colostrum, 28 g/L in bovine milk                   | Antihypertensive activity, Opioid agonists, anticarcinogenic | [3,4]      |
|                | $\beta$ -lactoglobulin   | 8.0 g/L in colostrum, 3.3 g/l in human milk                  | Immunomodulatory, Hypocholesterolemic                        | [4]        |
|                | $\alpha$ -Lactoalbumin   | Human milk (2.44 g/L) and bovine milk (1.2 g/l)              | Immunomodulatory, Hypocholesterolemic                        | [5]        |
|                | Immunoglobulins          | 60-80% of total protein in colostrum                         | Stimulate immune system                                      | [6]        |
|                | Lactoferrin              | 6-8 mg/mL in colostrum                                       | Antioxidant, antimicrobial, anti-inflammatory                | [7]        |
|                | Lysozyme                 | Human milk (3 to 3000 $\mu$ g/ml)                            | Antimicrobial  | [8]        |
|                | Lactoperoxidase          | 13-30 mg/L   | Antimicrobial  | [9]        |
|                | Conjugated linoleic acid | 2 to 53.7 mg/g fat   | Anticarcinogen, immunomodulatory properties                  | [10,11]    |
| Meat           | L-Carnitine              | 21.1 to 87.5mg/100g  | Metabolism of fat, prevent cardiovascular disease            | [12]       |
|                | Coenzyme Q10             | 1.4 to 4.6mg/100g  | Antioxidant, improve cardiac function                        | [13]       |
|                | Carnosine and anserine   | Carnosine (191 and 351 mg/100g), anserine (27 to 144mg/100g) | Anti-glycation, antiaging effects                            | [13]       |
|                | Lipoic acid              | 0.01 to 0.16 mg/100g   | Antioxidant  | [14]       |
|                | Creatine                 | 401 mg/100g  | Antioxidant, strengthen muscle                               | [15]       |
|                | Taurine                  | 43.1 to 61.2 mg/100g   | Maintain bile acid conjugation, osmoregulation               | [16,17]    |
|                | Conjugated linoleic acid | 1.2 to 19 mg/g fat   | Prevent CVD, anticancer                                      | [18]       |

|       |                       |  |   |         |
|-------|-----------------------|--|---|---------|
| Egg   | Lutein and zeaxanthin | Lutein (288 g/100g), zeaxanthin (279 g/100g) | Prevent age-related macular degeneration, antioxidant | [19,20] |
|       | Choline               | 20.6 mg/100g                                 | neurodevelopment and cognitive function               | [21,22] |
|       | Phospholipids         | 1.3g   | Prevent CVD, anti-inflammatory, anticancer            | [23]    |
|       | $\omega$ -3 PUFA      | 72 mg/ 2 eggs                                | Reduce risk of metabolic syndrome                     | [24,25] |
|       | Bioactive peptide     | -  | ACE-inhibitory, antioxidant                           |         |
|       | Lysozyme              | 3400 and 5840 mg/L                           | Antimicrobial   | [26]    |
| Honey | Phenolics             | 44.8 to 241.4 mg GAE/kg                      | Antioxidant, anticancer, antidiabetic, antimicrobial  | [27]    |
|       | Flavanoids            | 0.17 mg to 8.35 mgQE/100g                    |   | [28]    |

**Table 1:** Bioactive components of foods from animal sources and their suggested benefits for human health.

## Dairy Products

Milk is a fluid secreted from the mammary gland by the female. It is acknowledged as a complete food for the neonates as well as for adolescents and adults. It contains all the nutrients such as carbohydrates (lactose), proteins (casein and whey proteins), balanced source of lipids, vitamins, minerals and water [29]. Beside traditional components, milk consists of numerous biological active compounds that rise from proteins, enzymes or lipids. Bovine milk possess casein and whey protein as a major component of which casein constitutes about 80 per cent of the total protein and rest is whey protein composed of  $\beta$ -lactoglobulin,  $\alpha$ -lactoalbumin, immunoglobulin (IgGs), glycomacropetides, bovine serum albumin and minor proteins such as lactoperoxidase, lysozyme and lactoferrin. These sub-fractions of casein and whey protein provides unique biological properties such as antioxidant, antiviral, antimicrobial, and anti-carcinogenic effects. In most of the cases, the bioactivities of milk proteins in their native form are latent, being absent or incomplete but are activated upon proteolytic digestion, releasing bioactive peptides [30,31]. These peptides are also released by proteolysis during gastrointestinal transit or food processing specially during milk fermentation and cheese maturation that enriches the dairy products [31]. The major biologically active milk peptides are casomorphins, casokinins, casoxins, immunopeptides, lactokinins, lactoferrin, lactoferricin, phosphopeptides, etc. that are observed to impart positive effect on body like ACE-inhibitory or antihypertensive peptides, immunomodulatory, antioxidative, antimutagenic, probiotic activity, etc. [32,33]. The well-known ACE-inhibitory peptides

are Val-Pro-Pro (VPP) and Ile-Pro-Pro (IPP) that are identified in fermented milk when inoculated with strains of *Lactobacillus helveticus* and *Saccharomyces cerevisiae* [34]. Peptide obtained from  $\beta$ -casein and  $\alpha$ -casein are  $\beta$ -casomorphins and exorphins, respectively behave like morphine while peptide obtained from  $\kappa$ -casein fragments called casoxins behave as opioid antagonists [30]. Opioid peptides play an important role in analgesia action, euphoria, stomach aches, and allaying anxiety. On the other hand,  $\beta$ -lactoglobulin, a major form of whey protein has wide range of biological activities such as antihypertensive, antimicrobial, ant oxidative, ant carcinogenic, immunomodulatory, opioid, hypocholesterolemic, and other metabolic effects [35]. It exerts immunomodulator and emulgator effect and is able to bind minerals, fat-soluble vitamins and lipids that leads to their resorption [36].  $\alpha$ -lactalbumin is an excellent source of essential amino acids i.e. tryptophan and cystein, that act as a precursors of serotonin and glutathion, respectively. Therefore,  $\alpha$ - lactalbumin enriches diet helps in improving cognitive functions in stress-vulnerable subjects. Furthermore,  $\alpha$ - lactalbumin exhibit antiulcerative properties therefore protect the rat stomach mucosa against lesion caused by indomethacin [37]. A tripeptide Gly-Leu-Phe produced from  $\alpha$ -lactalbumin possess immunomodulatory effect that stimulates phagocytosis of macrophages and neutrophils [38]. Lactoferrin, an iron binding and transport protein, and its derived peptide lactoferricin supplies nourishment to intestinal microflora. It endows both bacteriostatic and bacteriocidal action by depriving iron required for microbial growth, binding directly to microbial membrane, respectively. Immunoglobulin provides massive immunity to the infants. Along with this certain cytokines

and chemokines like interleukins, chemokines, interferon- $\gamma$  and growth factor are produced in human milk that contribute to development and function of immune system [39]. In recent year, advances in bio separation techniques have made possible to fractionate and enrich antibodies by immunizing cows with vaccines to formulate immune milk preparations [40].

Mammalian milk also constitute about more than 60 different enzymes like lysozyme, catalase, superoxide dismutase, lactoperoxidase, myeloperoxidase, xanthine oxidoreductase, ribonuclease, etc. that account for antioxidant and antimicrobial properties. Therefore, helps in milk stability and protecting mammals against pathogenic agents [41]. The milk of all mammals virtually contains lysozyme that belongs to the c-type. The innate defence mechanism of lysozyme involves breakdown of peptidoglycan polymers of bacterial cell wall at the  $\beta$ 1-4 linkage between N-acetylmuramic (NAM) acid and N-acetylglucosamine (NAG) residues, thereby lysing sensitive bacteria. It acts either independently by lysing sensitive bacteria or as a component of complex immunological reactions to enhance the phagocytosis of bacteria by macrophages [42]. In addition, the presence of other antimicrobial milk proteins such as Immunoglobulin A (IgA) and lactoferrin were shown to significantly enhance lysozyme activity against trophozoites of *Entamoeba histolytica* [43]. Also, lactoperoxidase present in bovine milk show bactericidal and bacteriostatic effect. The lactoperoxidase system consists of three primary components: lactoperoxidase enzyme, thiocyanate,

and hydrogen peroxide. This system generates hypothiocyanite, an active compound, working against Gram-positive and Gram-negative bacteria, including *Escherichia coli* [44]. Hypothiocyanite, a product of LPOS act as a natural biopreservative have been generally recognized as a safe [45].

Other than milk protein, bovine milk fat has also shown certain health benefits. Conjugate Linoleic acid (CLA), also known as Rumenic Acid (RA) is the most active bioactive lipid in milk. It is synthesized by linoleic acid. The principal dietary CLA is cis-9, trans-11 isomer, that account for 73-94 per cent of the total CLA in milk, dairy products, meat, and processed meat products of ruminant origin. Many studies have confirmed the preventive role of CLA against cancer and atherosclerosis, diabetes, modulates immune response and enhances bone growth [46]. Dietary CLA is efficient in suppressing tumor development during initiation, promotion and progression phases of carcinogenesis [47] and is able to normalize impaired glucose tolerance in diabetic rats [48]. CLA has been reported for immunomodulatory properties by enhancing mitogen induced lymphocyte blastogenesis, lymphocyte cytotoxic activity and macrophage killing ability [49]. Furthermore, milk fat is also enriched with EPA (C20:5 n3) and DHA (C22:6 n3) that are associated with reducing the risk of cardiovascular disease, type-2 diabetes, hypertension, and carcinogenic agent. Table 2 reflects the observation made by different scientist using physiologically active compound present in dairy products and their suggested benefits for human health.

| Source | Bioactive compound  | Work   | Activity  | Reference |
|--------|---|--|---|-----------|
| Milk   | Bioactive peptide: Ile-Pro-Pro, Val-Pro-Pro and Leu-Pro-Pro | <i>In vitro</i> action of IPP, VPP and LPP against renin-angiotensin system enzymes: ACE1, ACE2, chymase, and cathepsin G. | Inhibition of ACE1 and ACE2, no effect on chymase and cathepsin G; reduce high blood pressure                   | [50]      |
|        | Bioactive peptide: Ile-Pro-Pro and Val-Pro-Pro              | Twenty-five subjects were provided with 25 mg peptides and 2 g plant sterols   | Antihypertensive activity, increase urinary excretion of cGMP, the second messenger of endothelial nitric oxide | [51]      |
|        | Bioactive peptide   | Peptide milk containing tripeptides 5 to 50 mg/day   | Reduces arterial stiffness expressed as AIx in hypertensive subjects.   | [52]      |
|        | Bioactive peptide   | Hydrolysis of caseins and whey proteins of goat milk by pepsin   | Antioxidant activities  | [53]      |
|        | Bioactive peptide: Thr-Ser-Lys-Tyr-Arg                      | $\alpha$ -137-141 fragment of hemoglobin produced by hydrolysis using pepsin.  | Act as preservative (0.5%, w/w), reduce the lipid oxidation, delay meat rancidity, antimicrobial effects        | [54]      |

|      |   |  |  |      |
|------|---|--|--|------|
|      | Bioactive peptide   | Peptide fractions (<3 and 3-10 kDa) obtained from milk fermented using <i>Lactobacillus plantarum</i> strains  | Anti-inflammatory, antihemolytic and antioxidant activity  | [55] |
|      | Immunoglobulin  | Administration of oral hyperimmune bovine IgG thrice a daily   | Protection against enterotoxigenic <i>Escherichia coli</i>   | [56] |
|      | Immunoglobulin  | Children suffering from respiratory tract infection or diarrhea received bovine colostrum for 4 weeks.   | Protection against recurrent RTI and diarrhea  | [57] |
|      | Immunoglobulin  | Oral administration of skimmed and concentrated bovine late colostrum (SCBLC) once before inoculation of HRV   | Prevent human rotavirus that induce gastroenteritis in immunocompromised hosts   | [58] |
|      | Lactoperoxidase   | Bovine lactoperoxidase (LPO) was purified from skimmed milk  | High antifungal and antibacterial activity against <i>Candida albicans</i> , <i>Candida parapsilosis</i> , <i>Escherichia coli</i> , <i>Streptococcus pneumonia</i> , <i>Staphylococcus intermedius</i> , etc. | [59] |
|      | Conjugated Linoleic Acid (CLA)  | 38 volunteers (29w, 9m) provided with T1 as 200 ml/day of skimmed milk with 3g of CLAs, T2 as 3g olive oil (placebo).                                | CLA group experienced reduction in total fat mass and body weight  | [60] |
|      | Conjugated Linoleic Acid (CLA)  | Women's consumption of high-fat dairy foods  | Reduces colorectal cancer  | [61] |
|      | Conjugated Linoleic Acid (CLA)  | Consumption of cis-9, trans-11 CLA enriched ultra-heat-treated milk, butter, and cheese consumed for 6 week. Control- 0.151 g/d, Modified- 1.421 g/d | Decrease cardiovascular disease risk variables, inflammatory markers, LDL cholesterol  | [62] |
|      | Conjugated Linoleic Acid (CLA)  | Consumption of trans-18:1 fatty acids an/r cis-9,trans-11-18:2 (rumenic acid) rich butter in atherogenic diet for 6 or 12 weeks                      | Decrease perirenal adipose tissue weight, lipogenic enzyme and lipoprotein lipase activities   | [63] |
| Meat | Bioactive peptide: GPV (Gly-Pro-Val) and GPL (Gly-Pro-Leu)  | Isolated ACE-inhibitory peptide from bovine skin gelatin hydrolysate using protease treatments (alcalase, pronase E and collagenase)                 | Anti-hypertensive (ACE-inhibitory activity)  | [64] |
|      | Bioactive peptide: HNGN (His-Asn-Gly-His)   | Hydrolysate from porcine plasma  | Antioxidant activity   | [65] |
|      | Bioactive peptide: Arg-Pro-Arg from nebulin, Lys-Ala-Pro-Val-Ala and Pro-Thr-Pro-Val-Pro from titin | <i>In vitro</i> gastrointestinal digestion of pork meat after oral administration to Spontaneously Hypertensive Rats (SHR)                           | Antihypertensive activity  | [66] |

|     |                       |  |   |      |
|-----|-----------------------|--|---|------|
|     | L-carnitine           | Patients with type I or type II diabetes given LC 2 g/day for 10 months.   | Improve peripheral neuropathy and ventricular dispersion; Prevent the increased incidence of arrhythmias and sudden death                                     | [67] |
|     | Coenzyme Q10          | Examine the relationship between plasma levels of coenzyme Q10 and vitamin B <sub>6</sub> with respect to CAD  | Reduced risk of Coronary Artery Disease (CAD)   | [68] |
|     | Coenzyme Q10          | Supplementation of coenzyme Q10 in CAD patient   | Reduce inflammatory marker IL-6, increase superoxide dismutase activities.  | [69] |
|     | $\alpha$ -Lipoic acid | Subjects are provided with $\alpha$ -Lipoic acid once @ 800 mg/day for 12 weeks  | Reduction of vascular constriction in the brachial artery, reduces risk of CV disease in overweight/obese youths.   | [70] |
| Egg | Bioactive peptide     | Three ovomucin hydrolysates were prepared using pepsin, trypsin and alcalase   | Inhibit Tumor Necrosis Factor (TNF), mediated nuclear factor kappa-light; Anti-inflammatory activity, maintain dermal health and prevent skin diseases.       | [71] |
|     | Bioactive peptide     | Bioactive peptide Arg-Val-Pro-Ser-Leu by hydrolysis of egg white protein by using alcalase   | Angiotensin Converting Enzyme (ACE)-inhibitory activity, antioxidant property, anticoagulation activity and stability against protease digestion.             | [72] |
|     | Lutein and zeaxanthin | Consumption of 1 egg /day for 18 weeks   | Increased serum lutein 26% and zeaxanthin 38%, no effect on serum concentrations of total cholesterol, LDL cholesterol and HDL cholesterol                    | [73] |
|     | Lutein and zeaxanthin | One hundred healthy volunteers<br>Group 1- one normal egg; Group 2- lutein enriched egg-yolk based beverage; Group 3- one lutein enriched egg; Group 4- one zeaxanthin enriched egg; Group 5- control group  | No changes in macular pigment density<br><br>Increase in serum lutein and zeaxanthin levels on consuming egg as compared with a daily use of 5 mg supplements | [74] |
|     | Phospholipids         | Feed mice for 3 weeks: (1) a high-fat semi-purified diet (HF); (2) HF diet supplemented with 1.25 wt% soy PC (SPC); (3) HF with 1.25 wt% hydrogenated soy PC (SPCH); (4) HF with 1.25 wt% egg PC (EPC); (5) HF with 1.25 wt% hydrogenated egg PC (EPCH). | SPCH and EPCH reduce total liver lipid and hepatic cholesterol  | [75] |
|     | Phospholipids         | Consumption of Carbohydrate Restricted Diet (CRD) 10-15% energy from carbohydrate + 3 eggs/day (640 mg/d additional dietary cholesterol)   | Decrease body weight and risk factors associated with MetS, improve plasma Triglycerides (TG), increase HDL-C   | [76] |

|       |                              |   |   |      |
|-------|------------------------------|---|---|------|
|       | Phospholipids                | Overweight men [body mass index (BMI) 26-37 kg/m <sup>2</sup> ] consume eggs (640 mg additional cholesterol/day provided by eggs)   | Reduce body weight, percent total body fat trunk fat and plasma CRP; Anti-inflammatory effects of CRD   | [77] |
|       | Phospholipids                | Subject with MetS consume 3 whole egg under carbohydrate-restricted diet (<30% energy) for 12 weeks.  | Improve dyslipidemia; Decreases waist circumference, weight and percent body; Reduction in plasma tumor necrosis, improves inflammation   | [78] |
| Honey | Honey                        | Treatment of MDA-MB-231 cell lines (breast cancer cell) with Sidr honey (H1) and Wild honey (H2) for 6, 24, or 48 h   | Anticancer effect, H1 and H2 reduce cell viability by 48% and 91% respectively  | [79] |
|       | Bee honey and Nigella grains | Four groups of Sprague Dawely rats.<br>Group: control; group 2: MNU (single i.v. dose 50 mg/kg body weight); group 3: MNU + after 1 week given orally 0.2 g ground Nigella grains; group 4: MNU + 0.2 g Nigella with 5 g honey/rat/day                                  | Protection against methylnitrosourea MNU-induced oxidative stress, inflammatory response and carcinogenesis   | [80] |
|       | Bee honey                    | Four groups of Sprague Dawely rats.<br>Group 1: control ( <i>ad libitum</i> ); group 2: <i>ad libitum</i> + 2 g honey/rat/day; group 3: DEN 150 mg k <sup>-1</sup> MNU + after 1 week given orally 0.2 g ground Nigella grains; group 4: DEN + after one week 2 g honey | Protective effect against diethylnitrosamine DEN-induced and inflammatory response, anti-hepatocarcinogenesis   | [81] |
|       | Manuka honey                 | Investigated antiproliferative activity of manuka honey on murine melanoma (B16.F1), colorectal carcinoma (CT26) and human breast cancer (MCF-7) cells  | Inhibit tumor growth; tumor apoptosis; alleviate chemotherapy-induced toxicity; anti-bacterial  | [82] |
|       | Honey                        | Streptozotocin-induced diabetic rats (60 mg/kg): group 1: Distilled water (0.5 mL/day); group 2: Honey (0.2 g/kg/day); group 3: Honey (1.2 g/kg/day); group 4: Honey (2.4 g/kg/day)   | Anti-oxidant activity: Increase activities of catalase, glutathione peroxidase, glutathione reductase, and glutathione-S-transferase, restore superoxide dismutase activity; Exerts hypoglycemic effect and ameliorates oxidative stress in kidneys | [83] |
|       | Tualang honey                | Male Sprague-Dawley rats consumed Tualang honey at different level 0.2, 1.2 and 2.4 g/kg  | Antinociceptive effects   | [84] |
|       | Aerosolised honey            | White rabbits sensitized with mixture of OVA and aluminium hydroxide on days 1 and 14. Treatment of aerosolised honey at doses (25% (v/v) and 50% (v/v))  | Reduces asthma symptoms by reducing the number of airway inflammatory cells; inhibit goblet cell hyperplasia.   | [85] |
|       | Manuka honey                 | Consumption of Manuka honey before exercise for 1, 2 and 3 week   | Reduce MDA and modulator of oxidative stress  | [86] |

**Table 2:** Clinical use of animal based bioactive in different pathophysiological conditions.

## Meat and meat products

Meat is the flesh and organs of different animals and fowls which is important for growth, maintenance and repair of the body. Meat is rich source of good quality protein with high biological value, vitamins including vitamin B<sub>2</sub>, vitamin B<sub>6</sub>, vitamin B<sub>12</sub>, pantothenic acid and niacin and minerals like iron, zinc, phosphorus and selenium [87]. Although some controversy is associated with meat and meat products due to high content of cholesterol and fat rich in saturated fatty acids (50% in beef, 40% in pork). But it was acknowledged that specific amino acids present in meat have positive impact on nervous and immune system, and also the peptides produced during digestion or food processing operation, may reduce the cardiovascular disease or hypertension [88]. Other than nutrients meat consists of endogenous antioxidants such as coenzyme Q10, glutathione, lipoic acid and histidyl dipeptides: carnosine and anserine and a source of conjugated linoleic acid and essential omega-3 polyunsaturated fatty acid possessing anticarcinogenic and antiatherogenic properties [89]. In addition, meat also has bioactive substances including L-carnitine, taurine, creatine and choline [88]. L-carnitine plays an active role in human fat metabolism that helps in carrying out fatty acids through the inner mitochondria membrane as L-carnitine ester. The deficiency of L-carnitine leads to improper oxidation of long-chained fatty acids in the mitochondria [90], and therefore results into energy deficit causing severe health impairments, especially at the cardiac muscle [90]. L-carnitine boosts fat combustion, reduces weight and increase performance of an athlete [90-92]. Supplementing diets with L-carnitine shows positive effect on age-dependent memory decline and learning capacity, and the attentiveness and concentration of Alzheimer's patients has also been improved with acetyl-L-carnitine [93,94]. L-carnitine is chiefly found in red meat, fish and dairy products. An antioxidative component i.e. Coenzyme Q10 or ubiquinone, is a vitamin-like substance which is soluble in oil. It acts as an electron carrier within this mitochondrial respiratory chain, thus preventing oxidative stress that occurs during accumulation of large quantities of oxygen radicals in an organism [95]. The antioxidant property of coenzyme Q10 is associated with its ability to exchange electrons between ubiquinol (reduced coenzyme Q10) and ubiquinone (oxidized coenzyme Q10) in a redox cycle. It prevents lipid peroxidation by delaying the production of lipid peroxyl radicals (LOO.) and ubiquinol reduces the initial peroxyl radicals, with simultaneous formation of ubisemiquinone (partially reduced form) and H<sub>2</sub>O<sub>2</sub>. Therefore, quenching of the initiating peroxyl radicals can protect both lipids and proteins from the oxidation process and makes coenzyme Q10 superior over other antioxidants [96]. In highest concentration it is being found in meat and fish. Lipoic Acid (LA) is an essential cofactor for different enzyme complexes in the mitochondria dehydrogenase reactions by transferring hydrogen and acyl groups for the energy and amino acids production

[97]. Furthermore, LA in its reduced form Dihydrolipoic Acid (DHLA) acts as radical scavenger and antioxidant. Alpha lipoic acid manage diabetes mellitus and improving dyslipidemia by maintaining glycemic control, decreasing reactive oxygen species generated by hyperglycemia and dyslipidaemia [98]. While on the other hand, glutathione plays a key role in cancer, Alzheimer's, Parkinson's, AIDS, cardiac infarct, stroke, etc. by detoxifying and eliminating carcinogens and toxins [99]. It is used in the synthesis of tissue hormones, regulation of gene expression, DNA and protein synthesis, the immune system, cell growth and death, and in signal transmission. Meat peptides, carnosine and its methylated form anserine play an important role in muscle tissue as pH buffer. It stabilizes the intra-muscular pH value and thus enhances the capacity during anaerobic performance by tolerating oxygen deficit [100]. Carnosine and anserine also reflects antioxidant activity thereby inhibiting the formation of AGEs (Advanced Glycosylation End-products) that increases with age related pathological circumstances such as diabetes, cataracts, arteriosclerosis and Alzheimer's disease [101]. Taurine is a sulphur containing amino acid which is not used for building up protein but perform an active role in various physiological functions like osmoregulation, bile acid conjugation, development of the retina and the nervous system, modulation of the calcium level and the immune function [102]. It possesses an antiarrhythmic effect therefore, increases regularity of contraction and the strength of the heart [103]. Table 2 reflects the observation made by different scientist using physiologically active compound present in meat products and their suggested benefits for human health.

## Egg

Egg is a conventional food containing considerable amount of nutrients with moderate calorie source (about 150 kcal/100 g) and an excellent protein quality and fat-soluble compounds [104]. Its great culinary versatility and low economic cost makes egg popular in most of the population. Its unique role in an embryonic form implies that egg consists of essential components that are important for life. It is a rich source of many bioactive compounds, such as protein and their derived bioactive peptides, lipid including phospholipids and omega-3 fatty acids, carotenoids and vitamin E that exhibit antioxidant, antihypertensive, and antiatherogenic properties. Furthermore, bioactive compounds like omega-3 fatty acids, vitamin E and xanthophylls can be enhanced further in eggs via feed manipulation. The presence of active proteins such as lysozyme, ovotransferrin, ovoinhibitor and cystatin in egg albumen prolongs the shelf life of table eggs. Lysozyme is effective against gram-positive bacteria while ovotransferrin is effective against gram-negative bacteria. It was reported that ovalbumin in egg white act as a source of amino acid for the developing embryo. Fujita et al. (1995) reported that the bioactive peptide, ovokin, derived from ovalbumin by the action of pepsin reduces the systolic blood pressure of spontaneously hypertensive rats [105]. In addition

to protein, lecithin a functional and structural component of all biological membranes increases the secretion of bile, preventing stagnation in the bladder and, consequently, decreases the lithogenicity [106]. Choline a component of lecithin acts in the rate-limiting step of the activation of membrane enzymes such as superoxide dismutase [107]. It is essential for brain development, helps in synthesis of phospholipids and metabolism of methyl and cholinergic neurotransmission [108]. In comparison to egg white, egg yolk represent itself as an important food source in improving plasma carotenoid level in a population suffering from CVD and type-2 diabetes [109]. Phospholipids, as a bioactive lipid in chicken egg yolk have potential effects on pathways related to inflammation, cholesterol metabolism, and HDL function. In addition, the lipid matrix of the egg yolk enhances the bioavailability of valuable carotenoid pigments, including lutein and zeaxanthin [110,111]. These carotenoids exert antioxidant effects against oxidative damage [112]. They get accumulated in the macular region of the retina and are collectively known as Macular Pigment (MP). AMD is allied with a low level of MP in the eye retina. Molecular mechanisms of lutein and zeaxanthin involved in the singlet oxygen and radical scavenging activity helps in decreasing or slowing down the light-induced oxidative stress in eye macular or AMD therefore good for eye health and vision [113-115]. Apart from MP, eggs have significantly greater amount of nutrient like vitamin A, E, folate, and B<sub>12</sub> [116]. Table 2 reflects the observation made by different scientist using physiologically active compound present in egg and their suggested benefits for human health.

## Honey

Honey is a natural substance produced by bees from honeydew or nectar of flowers. It is being valued for its therapeutic abilities since ancient times. Honey consists of different compounds like sugars, free amino acids, proteins, enzymes, essential minerals, vitamins, and various phytochemicals. The phenolic compounds, such as flavonoids and phenolic acids present in honey exert various therapeutic effects due to their antioxidant activity [117]. The radical scavenging and protection against the lipid peroxidation helps in preventing diseases and physiological situations arising due to oxidative stress. An *in vivo* study done by Schramm et al. (2003) reported the bioavailability of antioxidant compounds of honey to the human body. Consumption of honey at the rate of 1.5 g/kg body weight showed the increased level of phenolic antioxidants and plasma antioxidant capacity in healthy human subjects [118]. Various *in vitro* and *in vivo* studies have reported the antimicrobial, antiviral, antifungal, anticancer and antidiabetic activity of honey and the protective effect on cardiovascular, nervous, respiratory and gastrointestinal systems. The scavenging activity of honey counteract various neurologic pathologies occurred during aging. Oral administration of honey on mice and rats were able to reduce sleep time, improve anxiety, decrease convulsion and increases the pain threshold level, therefore leads to anti-hypnotic, anxiolytic,

anticonvulsant, and antinociceptive effects [84,119]. Regarding the antibacterial activity honey is effective against both Gram-positive and Gram-negative bacteria [120]. It sterilizes the wounds, stimulate tissue re-growth, reduces edema and scar formation, affects simple wounds, burns, diabetic foot ulcers, and pressure ulcers [121-123]. An enzyme glucose oxidase present in honey is also responsible for antimicrobial activity by converting glucose into  $\delta$ - gluconolactone, which is further hydrolyzed to gluconic acid and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>). Honey is also able to act against *Helicobacter pylori*, that is responsible for gastroduodenal ulcers [124]. In case of cancer, honey acts at different stages i.e. initiation, proliferation, and progression. The antitumoral effect is generally recognized based on different mechanisms, such as induction of apoptosis, modulation of oxidative stress, cell cycle arrest, amelioration of inflammation, induction of mitochondrial outer Membrane Permeabilization (MOMP) and inhibition of angiogenesis [125]. Honey possesses 30.91-44.26% of fructose whose metabolism is insulin independent therefore responsible for reduced postprandial glycemic response in diabetic and non-diabetic person [83]. Evidences has supported that the antidiabetic and the hypoglycemic capacity of honey is associated with its antioxidant activity that prevents the lipid oxidative metabolism in patients affected by type 2 diabetes mellitus [126]. Also various studies have been reported on the protective effect of honey on cardiovascular system due to presence of flavanoid and vitamin C following different mechanisms such as reduction of the activity of blood platelets, prevention of oxidation of LDLs and improvement of coronary vasodilatation. Ahmed et al. (2011) reported that honey was able to reduce the platelet aggregation by inhibiting coagulation through all three cascades (intrinsic, extrinsic and the common cascade) and decreased fibrinogen levels, therefore counteracting the process of atherosclerotic plaques formation [127]. Table 2 reflects the observation made by different scientist using physiologically active compound present in honey and their suggested benefits for human health.

## Conclusion

It is often recommended that the intake of animal source foods should be limited because of possible linkages between animal product consumption and health. There are various factors like complexity of the food substance, effects on the food, compensatory metabolic changes that may occur with dietary changes and lack of surrogate markers of disease development. This has lead to animal food in its infancy in the field of functional food. But with improves research and development, scientific evidence supports the beneficial role of animal source foods in preventing and combating obesity and certain non-communicable diseases related to over- nutrition. However, still there is a need of continuous investment in research and extrapolation of information towards appropriate guidelines and recommendations of animal based products. Additional research is necessary to substantiate the

potential health benefits of those foods for which the diet-health relationships are not sufficiently scientifically validated.

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