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PHYSIOLOGICAL EFFECTS AND HEALTH BENEFITS OF FEEDING OLIGOSACCHARIDES

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SUMMARY

Oligosaccharides possess several functional properties that lend them useful ingredients in animal feeds and human foods. They have been shown to serve as an indirect energy source and maintain the integrity of gastrointestinal mucosa. Because of their nutritional properties and physiological effects on the digestive system, oligosaccharides have been studied and were shown to stimulate mineral absorption and to increase the levels of hematocrit and hemoglobin concentration in the blood. Moreover, oligosaccharides have been found to increase, in the gut, the beneficial bacteria (Bifidobacterium Spp.) that alter luminal pH thus leading to inhibition of potential pathogens. Oligosaccharides are credited for stimulation of immune responses and restoration of normal intestinal flora. The use of oligosaccharides in poultry diets has resulted in improvement in weight gain, feed efficiency and reduction in Salmonella colonization. In pet animals such as dogs and cats, oligosaccharide supplementation in the diet was shown to improve digestibility of protein and amino acids and contributed to reduction in gas production in the lower gut.

Based on the available scientific information to date, oligosaccharides have the ability to reduce the risk of human diseases such as coronary heart disease, diabetes mellitus, and colon cancer. Oligosaccharides feeding had resulted in a reduction in lipid, glucose, triglycerides, and cholesterol levels in blood. The mechanisms by which oligosaccharides affect these blood metabolites and the practical implication of including

them in the diet have been reviewed in this paper.

INTRODUCTION

Oligosaccharides are a non-digestible complex of glucan- type carbohydrates that contain a number of monosaccharides, which resist hydrolysis by salivary and intestinal digestive enzymes. They cannot be digested in an animal's small intestine due to the absence of (-1,6-galactosidase in the intestinal mucosa (Gitzelmann and Auricchio, 1965). In the colon, anaerobic bacteria ferment them and volatile fatty acids are produced.

Among the non-digestible oligosaccharides, the chicory fructooligosaccharides occupy a key position and are recognized as natural food ingredients.The other major products are the short-chain fructooligosaccharides and galactooligosaccharides obtained by enzymatic synthesis using sucrose and lactose as substrate, respectively. For example, the soybean oligosaccharides such as the xylooligosaccharides are produced by partial hydrolysis of xylans, and polydextrose or pyrodextrins are prepared by a chemical treatment of carbohydrates. Inulin and oligofructose (fructooligosachaides) are non-digestible oligosaccharides derived from sucrose or isolated from natural vegetable source (Delzenne and Roberfroid, 1994).

Oligosaccharides, present as storage carbohydrates, are widely distributed in many plants and vegetables such as onions, garlic, chicory, wheat, soybeans, and bananas (Edelman and Dickerson, 1966). Oligosaccharides comprise 70% of wheat and about 25% of onions (Roberfroid, 1993), and are present in the daily diet of many of the world's populations (Van Loo et al., 1995). In most countries, wheat and onions constitute major natural food ingredients. Humankind has been exposed to oligosaccharides for centuries. Peasants's farmers (Fallaheen) in Egypt usually consume onions with the early morning meal.

Oligosaccharides composition in some common foods is presented in Table (1).

It has been found that oligoaccharides (sucrose) containing diets had a faster rate of passage than starch containing diets (Matoes et al., 1981).This high digestion rate causes low nitrogen-corrected true metabolizable energy as in conventional soybean meal fed to poultry which resulted in more gas production and acidity of the lower gut (Reddy et al., 1984) and more rapid intestinal digestion (Hellendoorn, 1979).When the oligosaccharides were removed from soybean meal by alcohol extraction, more fiber was digested, in chickens, because of a lower transit time and an enhanced cecal environment for the microbial hydrolyzation of polysaccharides (Coon et al., 1990). Oligosaccharides are comparable to dietary fibers in that they are composed of multiple saccharide units, which are not digested by the enzymes found in the mammalian small intestine. In addition, most polysaccharides associated with dietary fiber, as well as oligosaccharides, can be fermented by microorganisms (Schneeman, 1999). According to the Association of Official Analytical Chemists (AOAC, 1990) classification, resistant oligosaccharides were included in the dietary fiber complex.

Oligosaccharides possess several functional and nutritional properties that make them useful ingredients for inclusion in animal and human foods. They have been associated with several physiologic actions that have important effects on animal and human health. Some of these effects include the improvement of growth and feed efficiency in poultry, increasing mineral absorption, enhancing the growth of beneficial bacteria, and inducing immunocompetence in animals and man.

In this paper, the functional and nutritional properties of oligosaccharides and their effects on performance and physiological parameters and health in poultry, humans and other species were thoroughly reviewed.

Effects of oligosaccharides on growth and feed efficiency:

The use of sugars and complex carbohydrates in poultry diets was initiated early in this century (Barnes et al., 1979). Oligosaccharides have been shown to improve weight gain and feed efficiency of broiler chickens (Sims et al 1998). Chickens receiving lactosucrose showed slightly greater body weight gain and improved feed efficiency (Terada et al., 1994). Similarly, Ammerman et al., (1989) demonstrated that addition of fructo-oligosccharides enhanced the growth and production efficiency of broiler chickens. Recently, Sims et al. (1998) found that weight gain, feed consumption and mortality of broilers fed diets containing oligosaccharides were similar to those receiving a diet with standard growth promoters. Studies of Al-Rawashdeh et al. (2000 a & b) and Orban et al., 1997) have indicated similar findings on broilers raised under thermal stress conditions (Table 2).

Orban et al (1994) noted that feeding oligosaccharides to pigs resulted only in numerical improvement in weight gain and feed efficiency. It has also been noted that pig's performance was not as remarkable as that reported for other oligosaccharides in poultry and swine studies (Orban et al., 1995a & b).

In pet animals such as dogs and cats, oligosaccharide supplementation in the diet was shown to improve digestibility of protein and amino acids and contributed to reduction in gas production in the lower gut (Zou et al., 1996).

Based on these findings oligosaccharides proved to have the potential to enhance growth performance in animals, which can point to possible savings in feed and production costs.

Impact of oligosaccharides on mineral absorption:

Recently, there have been many reports indicating that indigestible carbohydrates, such as fructooligosaccharides (Ohta et al., 1997), inulin (Remesy et al., 1993), guar gum hydrolysate (Hara et al., 1996) and resistant starch (Schulz et al., 1993) stimulate mineral absorption (Table 4 and Table 5). Oligosaccharide feeding enhanced Ca^{2+} absorption. The stimulatory effect of oligosaccharides on Ca^{2+} and Mg^{2+} absorption mainly takes place in the large intestine (Ohta et al., 1997). The enhanced mineral absorption is due to a decrease in the luminal pH resulting from microbial fermentation of indigestible carbohydrates, which facilitates the dissociation of water insoluble dietary minerals (Schulz et al., 1993).

Feeding fructooligosaccharides promotes recovery from anemia in iron deficient rats (Ohta et al., 1995) by changing mucin composition, which increases iron and calcium absorption. It has also been found that, in rats, some duodenal proteins such as mobiferrin and calreticulin have affinity for both Ca^{2+} and iron (Conard et al., 1993). There are also calcium binding proteins that exist in the large intestine of rats (Petith et al., 1979). It was also postulated that propionate, which is produced by intestinal fermentation of fructooligosaccharides, may stimulate heme production (Imaizumi et al., 1992).

Several investigators have demonstrated that rats fed oligosaccharides absorbed more calcium and magnesium than the controls. (Ohta et al., 1994). They suggested that the effect of fermentation in the cecum was particularly important for Ca^{2+} absorption. The stimulating effect of indigestible carbohydrates may be attributed to reduction of luminal pH by microbial fermentation in the large intestine, dissolution of insoluble Ca^{2+} salts (Younes et al., 1996), or fermentation resulting from the production of short-chain fatty acids, which has been reported to stimulate Ca^{2+} absorption in humans (Trindad et al., 1996) and to induce the proliferation of epithelial cells (Sakata, 1987).

Indigestible carbohydrates reach the large intestine intact and are fermented by bacteria in the intestinal lumen, resulting in the production of organic acids such as acetate, propio-nate and butyrate. These acids may dissolve insoluble Ca^{2+} salts in the luminal contents and increase diffusive Ca^{2+} absorption via the paracellular route (Younes et al., 1996). Feeding oligosaccharides increases the levels of calcium binding protein (calbindin-D9k CaBP) in the large intestine and deceases it in the small intestine. This CaBP has a high affinity for Ca^{2+}, and it exists in the large intestine (Wilson *et al.*, 1981), and influences intracellular calcium transportation (Wassermann and Taylor, 1995). Therefore, it is likely that indigestible carbohydrates including oilgosaccharides stimulate Ca^{2+} absorption not only via the paracellular route, but also via the intracellular route.

Can immuncompetence be enhanced by oligosaccharides?

Immune response enhancement has been proposed as a possible function of oligosaccharides. The belief that feeding oligosaccharides boosts immunocompetence, which is the capacity for a normal immune response, has led to increased interest in feeding them to animals and humans (Moshfegh *et al.*, 1999). Lactulaose raises serum glutamine levels (Jenkins et al., 1997) by providing increased short-chain fatty acids. Because glutamine is a preferred substrate for lymphatic tissue, it is possible that this may improve immune function.

Gross and Siegel (1986) reported that feeding oligosaccharides may impact intestinal colonization of bacteria and the immune system, and this was indicated by total and differential white blood cells counts and heterophil/lymphocyte ratio. It has been observed that Lactobacilli are able to use and out-compete bifidobacteria when oligosaccharides are the primary carbon and energy source (Sghir *et al.*, 1998). Bifidobacterium and Lactobacillus are thought to exert health-promoting effects in animals and humans (Campbell *et al.*, 1997). Oligosaccharides play a role in boosting immunity was associated with lactobacilli or lactic acid forming bacteria. Schiffrin *et al.* (1995) reported that non- specific immune activity and phagocytic activity in peripheral blood was enhanced following ingestion of lactic acid bacteria in humans. The enhancement of phagocytic activity was considered to be due to an increased contribution by the granulocyte population. Similar findings were reported in rats by Perdigon *et al* (1988). It was also observed that lactic acid bacteria might enhance the non-specific resistance of the host to infections and tumors (Fernandes and Shahani, 1990) or act as adjuvants of specific immune responses (Wells *et al.*, 1993).

A type of oligosaccharides called human milk glycoconjugates are proved to act as a protective factor in the gut of infants. Oligosaccharides inhibit the adherence of S. pneumoniae, enteropathogenic E. coli and invasive C. jejuni, and also inhibit the toxicity of the heat -stable enterotoxin of E. coli (Newburg, 1997). The inhibition mechanism of Campylobacter is brought about by milk oligosaccharides, which have homologous receptors to cell surface receptors. Therefore, they can bind to pathogens and inhibit the ability of the pathogens to bind the cell surface receptor. A different mechanism against heat stable enterotoxin is that oligosaccharides may bind to the cell surface receptor and thereby inhibit the ability of the pathogen to affect the host cell (Newburg, 1997).

Oligosaccharides are also incorporated in treatment of diarrhea. (Buddington and Weiher, (1999), reported that the use ....of an oral electrolyte solution with fermentable fiber oligosacharides accelerates recovery of beneficial bacteria, reduces the relative abundance of detrimental bacteria, stimulates mucosal growth and enhances digestive and immune functions. Buddington and Weiher, (1999) concluded that fermentable fibers could be used as a management tool to promote gastrointestinal health in normal states and during recovery from diarrhea. Bacterial fermentation of fiber triggers the release of glucagons-like peptides 1 and 2, gastric inhibitor peptide and other enteric hormones. These then stimulate mucosal growth and upregulation and transport processes in the proximal intestine (McBurney *et al*, 1998).

The work of Al-Rawashdeh *et al.*(2000 a&b) documented that feeding dietary sucrose thermal oligosaccharides caramel (STOC) to growing ducks seems to enhance favorable changes in physiological parameters such as increasing heterophils number, heterophil / lymphocytes ratio and total serum protein and globulins, which may suggest an improvement in the immune system response in these birds. Given the economical considerations and concerns about antibiotics in poultry feeds, oligosaccharides should be further evaluated as a useful feed ingredient in poultry ration (Table 3, Table 4, and Table 5), whose feeding may reduce the pathogenic bacteria in the digestive tract of poultry and poultry products.

Physiological Parameters:

There are limited investigations regarding the effects of oligosaccharides on hematological parameters. Al-Rawashdeh *et al.*(2000a) studied the effects of feeding oligosaccharides on blood values of selected serum biochemical constituents, hormones, fibronectin and cecal gram negative bacteria counts in ducks fed diets without antibiotics. Feeding oligosaccharides resulted in significantly higher heterophils, total protein, albumin, globulin, and fibronectin, and decreased heterophil / lymphocytes ratio and a decreased basophil counts. Serum from ducks fed oligosaccharides had significantly more Ca^{2+}, higher P and increased anion gap, and lower triglycerides levels.

In broiler chickens it was found that birds fed oligosaccharides had higher but not significant MCV, heterophil and basophil counts, heterophil / lymphocytes ratio, serum total protein, globulin, creatinine, triglycerides and potassium. Dietary oligosaccharides have been shown to prevent anemia and osteopenia by increasing the level of hematocrit and hemoglobin concentration in gastroectomized rats (Ohta *et al.*, 1998). The results obtained by Al-Rawashdeh *et al.* (2000 b&c) have also shown a slight alterations in hematological profile in broiler chickens fed oligosaccharides and exposed to feed restriction, indicating that oligosaccharides may have a protective effect against thermal stress (Table 4 and Table5).

Acclimatization to stress:

Feed restriction:

Inclusion of oligosaccharides in poultry diets and feed restriction are some of the strategies that have received increased attention in efforts to improve production efficiency and reduce mortality and Salmonella colonization in broiler chickens. The effect of feeding STOC in birds exposed to feed restriction was studied by Al-Rawashdeh et al. (2000c), who observed that STOC could have a protective role since only slight alterations had occurred in the hematological profile and in the number of Gram-negative bacteria in broiler chickens.

Thermal Stress:

Heat stress is a major concern to the poultry industry because it causes decreased growth, high mortality, and poor performance (Eberhart and Washburn, 1993), and it has a negative impact on broilers economy. Studies of Al-Rawashdeh et al. (2000c) & Orban et al. (1997) have shown that inclusion of STOC with 1% vitamin-mineral premix in broiler diets improved weight gain of broiler chickens exposed to thermal stress. These results suggest that oligosaccharides may have played a protective role to counteract the adverse effects of high brooding temperature under which the birds were reared.

Microbial Ecology of the Gut:

Necrotic enteritis caused by C. perfringens (EL-Seedy, 1990) and Clostridium botulinium in chickens (Blandford *et al.*, 1970) and the subsequent food poisoning caused by chicken meat and meat products (Zen-Yoji *et al.*, 1970) have caused enormous economic losses. This has justified the practice of adding antibiotics and growth promoters to poultry diets to boost the economical and health impact in the poultry business. It has been shown that oligosaccharides act as growth promoters in chickens and could be substituted for subtherapeutic levels of antibiotics without development of resistant bacteria in the intestine (Ammerman *et al.*, 1989). It was found that the balance of intestinal flora is known to play an important role in the health and growth of its host (Mitsuoka, 1992).

Oligosaccharides have been shown to be utilized by only a few pathogenic and non-pathogenic intestinal bacteria in pure cultures (Hidaka *et al.*, 1986). However, in the competitive environment of the intestinal tract, fructooligosaccharides tend to selectively enrich the beneficial genera such as Lactobacilli and Bifidobacteria (Mitsuka *et al.*, 1999), and inhibit pathogenic bacteria such as Salmonella enteritis (Hidaka *et al.*, 1986). Fukata *et al.* (1999) stated that feeding fructooligosaccharides had reduced Salmonella colonization, and a similar observation was reported by Bailey *et al.*

(1991) who concluded that Salmonella did not grow when fructooligosaccharides were the sole carbon and energy source.

Studies reporting the use of fructooligosaccharides in poultry diets have indicated a reduction in intestinal colonization by Salmonella (Waldroup *et al* 1993). Feeding lactosucrose to broilers significantly increased numbers of bifidobacteria and decreased the counts of Clostridia, Bacteriodacae, Staphylococci, anaerobic bacteria and Pseudomonas in humans (Terada *et al.*, 1994). Similar observations were reported by Ogata *et al.* (1993). Studies using the kestose oligosaccharides (Patterson *et al.*, 1993) have shown that the ability of a number of pathogenic and non-pathogenic intestinal bacterial species to grow on these kestoses was consistent with the results of Hidaka et al. (1986). In addition, it has been shown that Bifidobacteria and Lactobacilli are selectively enriched in the ceca of broilers fed these kestoses oligosaccharides (Patterson *et al.*, 1993). The research of Orban *et al.*(1993, 1994& 1997); Patterson *et al.* 1997) and Al-Rawashdeh *et al.*(2000 a,b&c) demonstrated that STOC was a promoter of intestinal proliferation of beneficial bacteria (Table 3).

A significant reduction in numbers of total aerobes and coliforms was observed in the ceca of broiler chickens fed diets containing STOC (Orban *et al.*, 1997). On the other hand, studies of Al-Rawashdeh *et al.* (2000 a&b) have shown that no Salmonella was found in the ceca of the growing ducks and a reduction in numbers of gram-negative bacteria in the ceca of broiler chickens fed STOC. Thermally produced kestoses oligosaccharides increased the numbers of bifidobacteria and lactobacilli cecal contents of growing broilers (Patterson *et al.*, 1993).

There are several mechanisms by which oligosaccharides may exert their functions. It was postulated that . Bifidobacterium species produce acetic and lactic acids during fermentation of oligosaccchardes resulting in a lower luminal pH, which prevents enteric colonization of potentially pathogenic microorganisms. (Gibson and Roberfroid, 1995) . A significant increase of cecal acetic acid (Terada *et al.*, 1994) in lactosucrose fed groups showed a positive correlation with the numbers of bifidobacteria. The change of the intestinal flora may lead to lower pH and a decrease in cecal putrefactive products, resulting in the accumulation of acetate (Bullen *et al.*, 1976) and in the increase of volatile fatty acids (Corrier et al., 1990) in the intestine. Hinton *et al.* (1990) noted that chicks given lactose had significant increases in the lactic acid concentration of their cecal contents, which was directly correlated to decreased cecal pH. Feeding lactose to chicks not only caused a reduction in the total concentration of volatile fatty acids but a significant increase in the undissociated form of some volatile fatty acids. The reduction of pH is important in reducing cecal colonization because it increases the concentration of the undissociated form of the volatile fatty acids (Meynell, 1963), which in turn have antibacterial (anti-salmonella) activity (Bohnhoff *et al.*, 1964). The low concentration of volatile fatty acids plus the high pH of the intestine of the newly hatched chicks are among the reasons why young chicks are more susceptible to Salmonella colonization than mature chickens (Barnes *et al.*, 1979).

Carbohydrates, such as mannose and lactose, have been found to lower the pH of the chicken intestinal tract (Oyofo *et al.*, 1989). It was also found that mannose decreased colonization of the gut by inhibiting the adherence of S. typhimurium to the intestinal mucosal epithelium (Oyofo *et al* 1989). On the other hand, oligosaccharides serve as an indirect energy source for the large intestine and play a critical role in maintaining mucosal cell differentiation and consequently, the integrity of the gastrointestinal mucosa.

The effects of various non-digestible oligosaccharides on the composition and metabolic activity of intestinal flora in humans are well documented (Okazaki *et al.*, 1990). Oligosaccharides increase the density of bifidobacteria and lactobacilli, which are beneficial intestinal bacterial, and enhance the growth of fecal bifidobacteria (Yoneyama *et al*, 1992) and cause a decrease of fecal clostridia in humans (Hara *et al.*, 1994) and other animals (Terada *et al.*, 1992b). The addition of short-chain fructooligosaccharides in human diets increases bifidobacteria counts (Bouhnik *et al*, 1996). Human milk oligosaccharides inhibit the binding of Streptococcus pneumoniae (Anderson *et al.*, 1986) and enteropathogenic E. coli (Cravioto *et al.*, 1991) to their receptors. Fructosylated oligosaccharides inhibit the toxicity of E.coli in vivo (Newburg , 1997) and the binding of invasive strains of Campylobacter jejuni to its host cell (Ruiz- Palacios *et al*, 1992) by competing with the receptors present in epithelial cells (Ohta *et al*, 1998).

Disease Prevention:

The use of oilgosaccharides in poultry proved to be advantageous in enhancing growth and performance. It has also a potential for boosting immunity. Understandably, research has gone further in using oligosaccharides for disease prevention in humans. Therefore, most of the health benefits discussed in this paper are related to humans as the ultimate beneficiary. The targets for oligosaccharide effects, as have been mentioned earlier, are the colonic microflora, the gastrointestinal physiology, the immune functions, the bioavailability of minerals and the metabolism of lipids, and colonic carcingenesis. Potential health benefits for humans include reduction of risk of colonic diseases, nonisulin-dependant diabetes, obesity, osteoporosis and cancer (Roberfroid, 1999).

Dietary administration of oligosaccharides inhibits the colonic aberrant crypt foci, preneoplastic lesions in the colon, (Reddy, 1999).The effects of oligosaccharides involve the enormous increase of bifidobacteria which bind the ultimate carcinogen by physically removing it via feces. Bifidobacteria also produce lactic acid, which lowers the intestinal pH to create a bactericidal environment for active enteropathogens such as E. coli and Clostridium perfringens. As a result, this creates a favorable environment, which involves the modulation of bacterial enzymes such as β-glucuronidase that can convert procarcinogens to proximate carcinogens (Kulkarni and Reddy, 1994). In addition oligosaccharides increase the production of short-chain fatty acids, especially butyrate, in the colon by microbial fermentation (Gibson and Roberfroid, 1995). This results in the inhibition of colon-rectal tumor cell proliferation (Gamet *et al.*, 1992).

It has been shown that fermentable fiber enhances epithelial proliferation (Howard *et al*, 1995). The effects may be due to providing more butyrate, which is the principal metabolic substrate for colonic epithelium (Roediger, 1980ab). On the other hand, it has been reported that (Roediger, 1980b) impaired utilization of short-chain fatty acids has been implicated in ulcerative colitis suggesting an energy-deficient state. Butyrate oxidation provides more than 70% of the oxygen consumed by humanís colonic tissues (Roediger, 1980a). Mucosal cells deficient in butyrate oxidation reflect a metabolic defect in the mucosa of ulcerative colitis patients. Moreover, Harig *et al* (1989) inferred that diversion colitis represented an inflammatory state resulting from a nutritional deficiency that may be effectively treated with enemas containing the missing short-chain fatty acids. The combination of bifidobacteria and oligosaccharides has also a symbiotic effect in reducing colon cancer risk in carcinogen treated rats (Gallaher and Khil, 1999).

In chickens cecal concentration of ammonia, phenol and cresol was greatly reduced by lactosucrose consumption resulting in a deodorant effect on the pen environment

(Terada *et al.*, 1999). Similar findings were obtained by Hussein *et al.* (1999) who reported that oligosaccharides supplementation numerically decreased the concentrations of ammonia and amines in dogís feces. In humans, subjects consumed oligosaccharides have been observed to deodorize stools (Terada *et al.*, 1992).

It has been found that oligosaccharides significantly decrease serum insulin and glucose, and increase intestinal production of incretins, glucose-dependent insuliotropic peptide and glucagons-like peptide1 (Delzenne and Kok, 1999). It was also reported that ingestion of oligofrucose reduces postprandial glycemia and insulinemia in rats (Kok *et al.*, 1996b). The possible mechanism by which fructooligosaccharides affect the physiology of the gastrointestinal tract and reduce insulin and glucose is by modification of the kinetics of dietary carbohydrates absorption, leading to modifications of both serum glucose and hormones (insulin and glucagons) and through acarbonse, an intestinal glucosidase inhibitor that delays starch digestion and reduces insulin and glucose (Maury *et al.*, 1993). A similar observation was reported by Luo *et al.* (1996) in humans, who found that fructooligosaccharides decreased basal hepatic glucose production. A non-significant reduction in blood glucose of broiler chickens fed oligosaccharides was observed by Al-Rawashdeh *et al.* (2000c).

The hypotriglyceridemic effect of nondigestible but fermentable carbohydrates including resistant starch or oligosaccharides has been described in both humans (Glore *et al.*, 1994) and animals (Roberfroid and Delzenne, 1998). Oligosaccharides significantly lowered triacylglycerol and phospholipid serum concentrations in rats (Delzenne *et al.*, 1993). The research done by Al-Rawashdeh *et al.*(2000c) showed that broiler chickens fed oligosaccharides had significantly lower triglycerides and creatinine serum levels. Similar reduction in triglycerides plasma levels were reported by Trautwein *et al.* (1998) in hamsters fed inulin. They attributed the lowering action to alterations in hepatic triacylglycerol synthesis or impaired reabsorption of circulating bile acids. Kok (1999) reported similar hypolipidemic effects of oligosaccharides in rats.

When oligosaccharides were used in higher percentages, they lowered cholesterol in hamsters (Trautwein *et al.*, 1998. A decrease in cholesterol of broiler chickens that were fed a diet containing a low percentage of oligosaccharides was not observed (Al-Rawashdeh *et al.*, 2000c), because high fiber contents in poultry diets may have a negative effect on the digestive process. The possible mechanism of reducing triglycerides by oligosaccharides appear to be due to its antilipogenic action in the liver by reducing the activity and possibly the expression of all lipogenic enzymes (Delzenne and Kok, 1999). The cholesterol lowering effects of soluble or viscous fibers relate to their gel-forming properties (Anderson, 1995a).

The evidence for links between dietary fibers and atherosclerotic cardiovascular disease is very strong; it arises from animal studies (Pilch, 1987), epidemiological observations (Rimm *et al.*, 1996) and clinical trials (Anderson, 1995a). Higher levels of fiber intake were associated with lower rates of myocardial infarctions and death from coronary heart disease among United States male health professionals (Rimm *et al.*, 1996). Dietary soluble viscous fibers effectively decrease serum cholesterol and LDL cholesterol concentrations, which may contribute to their protective role against coronary heart disease (Anderson *et al.*, 1990).

Breast cancer and tumor growth were significantly inhibited by supplementing the diet with oligosaccharides in rats. The mechanism of tumor growth inhibition is through the inhibition of glucose and fatty acid pathways (Cay *et al.*, 1992) by oligosacharides, because tumor cells depend on glucose and endogenous fatty acids synthesis for their energy (Kuhajda *et al.*, 1994). Feeding a combination of bifidobacteria and oligosaccharides reduces colon cancer risk in carcinogen treated rats (Gallaher and Khil, 1999).

Practical Implications:

Oligosaccharides are not digested in the upper gastrointestinal tract, but they are completely fermentable in the cecum and colon (Roberfroid, 1999). Commercial grades of oligosaccharides are available on the industrial food ingredient market for humanís consumption. They have a neutral, clean flavor, and they are used to improve the stability of low fat foods in the body. They are used to fortify food with fiber.

There is a need for practical dietary supplementation of oligosaccharides in animal food ingredients. Based upon research involving canine (Willard *et al.*, 1994) and feline (Buddington and Sunvold, 1998, Hussein *et al*, 1998) species, there is a need for supplementation of oligosaccharides in their diets. Due to the lack of database on oligosaccharide concentration in petfood ingredients, its use for wide scale commercial production is not yet feasible. In order to incorporate oligosaccharides into human and animal diets and to receive the benefits provided by oligosaccharides, it is essential to expand the database.

As mentioned earlier, there are many benefits from oligosaccharides intake that could impact animal and human health. For instance oligosaccharides have the ability to reduce feces odor, which helps improve the environment and air quality in poultry houses and eliminate the nuisance in the neighborhood. Similarly, elimination of fecal odor from dogs and cats feces will improve the indoor environment, giving convenience and pleasure to pet lovers to enjoy their companionship.

Using oligosaccharides in animal and human foods will have a significant economical impact because it will reduce the cost of health care and medications. The development of commercial foods that include oligosaccharides will improve food quality and consumer and animal well-being. Inclusion of oligosaccharides in poultry diets will provide an opportunity to improve the wholesomeness of poultry products by eliminating harmful bacteria and putrefactive voided substances.

Table (1): Oligosaccharides (imulin and oligofructose) contents in some foods (g/100g)

Food	Inulin		Oligofructose	
	Range	Average	Range	Average
Banana				
Raw	3-7	.5	-3-.7	.5
Chicory				
Raw	12-15	13.5	9.6-12	10.8
Dried	20.3-36.1	28.1	8.1-14.5	11.3
Onions				
Raw	1.1-7.5	4.3	1.1-7.5	4.3
Dried	4.7-31.9	18.3	4.7-31.9	18.3
Cooked	8-5.3	3	.8-5.3	3
Wheat				
Bran	1-4	2.5	1-4	2.5
Flour baked	1-3.8	2.4	1-3.8	2.4
Flour-boiled	.2-.6	.4	.2-.6	.4
Barley				
Raw	.5-1	.8	.5-1	.8
Cooked	.1-.2	.2	.1-.2	.2

Source: Van Loo et al.(1995)

Table (2): Feed intake, weight gain, and feed conversion of male broiler chickens fed starter diets containing antibiotic or sucrose thermal oligosaccharide carmel (STOC) from day-old to 4 wk of age.

Criteria/ treatment	Weeks				Cumulative
	1	2	3	4	1 to 4 wk
Weight gain,g:					
Control	66	111	245	347	763
Antibiotic	68	128	277	356	822
STOC, 3.7%	96	210	353	454	1.124
STOC, 7.5%	98	203	325	451	1.080
SEM	3	5	6	6	15
Probability	0.001	0.001	0.001	0.001	0.001
Feed intake,g:					
Control	119	272	371	779	1.543
Antibiotic	118	283	406	802	1.607
STOC, 3.7%	127	332	503	798	1.771
STOC, 7.5%	131	341	497	817	1.790
SEM	2	5	7	8	11
Probability	0.0009	0.001	0.001	0.322	0.001
Feed conversion:					
Control	1.79	2.50	1.52	2.25	2.02
Antibiotic	1.74	2.23	1.47	2.26	1.96
STOC, 3.7%	1.32	1.58	1.42	1.76	1.58
STOC, 7.5%	1.35	1.70	1.54	1.81	1.66
SEM	0.03	0.06	0.02	0.05	0.03
Probability	0.001	0.001	0.0001	0.001	0.001

Source: Orban et al.(1997)

Table (3): Influence of oligosaccharides on some physiological parameters* in White Pekin Ducks (significant effects).

Item	Least Square Means		
	Control	STOC	SEM
Heterophil, 103ml-1	5.90	16.20	3.80
Heterophil: lymphocyte ratio	1.70	8.20	8.00
Basophil, 10-ml-1	0.60	0.30	0.05
Ca, mg/Dl	10.44	10.77	0.10
P, mg/dl	7.11	8.07	0.25
Anion gap, mmpl/L	11.28	13.37	0.51
Body weight,g	1277.30	1376.57	24.52
Total protein, g/dl	2.71	3.01	0.07
Albumin, g/dl	1.27	1.40	0.03
Fibronectin (plasma), ng/dL	255.04	326.07	13.04
Fibronectin (serum), ng/dL	144.30	288.00	21.27
Gram negarive bacteria, log10	5.80	4.30	1.00

* $P<0.05$
Source: AL-Rawashdeh et al.(2000)

Table (4): Influence of feeds on some blood metabolites in broiler chickens

Item	Least Square Control	Means	
		STOC	SEM
Total serum protein, g/L	2.99	3.32	0.09
Globulin, g/L	1.62	1.82	0.06
Creatinine, mg/dL	0.20	0.17	0.01
Triglycerides mg/dL	73.75	28.38	7.09

* $P<0.05$
Source: AL-Rawashdeh et al.(2000).

Table (5): Cecal bacterial population of broiler chickens fed starter diets, containing antibiotic or sucrose thermal oligosaccharide caramel (STOC) at 4wk of age.

Cecal bacteria populations								
Aerobes				Anaerobes				
Treatment	Total		Coliforms	Total Log_{10}	Clostridia cfu per	fecal	Lactobacilli content DM	Bifidoba
Control	9.43		9.00	10.90	6.21		9.16	5.98
Antibiotic	9.31		9.25	10.75	6.06		9.10	6.99
STOC,3.7%	9.02		8.92	10.88	6.00		8.63	7.47
STOC, 7.5%	9.07		8.95	10.85	6.14		8.95	7.39
SEM	0.14		0.09	0.04	6.15		0.13	0.14
P-value	0.465		0.156	0.148	0.705		0.054	0.033

Source: Orban et al.(1997)

CONCLUSION:

It can be concluded that, oligosaccharides are multipurpose food ingredients with an impact on both animal and humans physiology, nutrition, health, economy and environment. Thus, provision of oligosaccharides as ingredients in nutritional formulas could produce convenient and affordable foods. Further research is needed to expand database to cover the different types of oligosaccharides. Incorporation of oligosaccharides in prescription diets of monogastric and pet animals is of paramount importance.

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