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Beta-glucans in dog food

Beta-glucans are water-soluble plant fibers, comprising chains of up to 2000 glucose units in so-called beta form. Glucose is a simple sugar, existing in solution as mixture of alpha and beta rings. The glucose building blocks of beta-glucans are joined by one of three linkage types. Beta-glucan constructions can differ as to linkage pattern, spatial structure and functionality. Cellulose is a water-insoluble beta-glucan with only one linkage type; this plant fiber is not discussed here.

Corn, rice, barley, wheat and oat contain different amounts of similarly linked beta-glucans. Another type of beta-glucans is found in baker's yeast. The five cereal grains and yeast are commonly used as petfood ingredient. Dog-food labels rarely highlight the beta-glucans in whole cereals and yeast. In contrast, added concentrates of beta-glucans, isolated from the outer layer of baker's yeast, are reputed to strengthen dog's immune system.

Free beta-glucans are recognized by immune cells in the intestinal wall. As a result, certain specialized cells may more efficiently capture and disarm harmful bacteria and viruses, while others produce more offensive antibodies. Such immunostimulation has been shown in dogs challenged with foreign substances (antigens), while ingesting purified beta-glucans derived from yeast or oyster mushroom. The amount ingested was equivalent to 0.08 % in dry food. Similar diet intervention also relieved symptoms in dogs with inflammation in joints, skin or bowel.

In dogs, food with added, purified beta-glucans can stimulate the immune response elicited by antigens. The risk, if any, of overstimulation is unknown. There is no evidence that extra intake of beta-glucans, as purified additives, prevents development of diseases in dogs. Nevertheless, beta-glucans did ameliorate inflammatory diseases.

Sources and chemistry

Beta-glucans in the aleurone layer of cereal grains have linear, bended structures. Their cellulose-like fragments, generally consisting of three or four of glucose units with β-(1, 4) bonds, are interrupted by a single β-(1, 3) linkage. Beta-glucans from yeast (*Saccharomyces cerevisiae*) comprise β-(1, 3)-linked glucose residues with small numbers of β-(1, 6)-linked branches.

The approximate levels of total beta-glucans in cereal grains are as follows: corn, 1.0%; rice, 0.7%; barley, 3.8%; wheat, 0.8%; oat, 3.7% (1-5, Note 1). Dried spent brewer's yeast has about 11% total beta-glucans (6-9). Yeast preparations marketed as immune stimulator contain some 60% beta-1,3/1,6-glucans (6, 10). Dry food with 50% of a grain species holds 0.35 to 1.9% cereal beta-glucans. Food with 1% dried brewer's yeast or a derivative, contains 0.1 or 0.6% yeast beta-glucans.

Macronutrient digestibility

Beta-glucans are resistant to the dogs' digestive enzymes, but are degraded by the colonic bacteria. Barley beta-glucans were moderately fermented by dog fecal microflora (11, 12). High intakes of beta-glucans may raise ileal digesta viscosity, thereby impairing digestion. In dogs dosed with oat-derived beta-glucans at a rate of 1% of the dry food offered, apparent digestibility of dry matter was reduced by 4.6 %units, while fecal mass grew larger and loosened up (13).

In dogs, apparent digestion of protein in dehulled barley was 3.5 %units lower than that for wheat (14, 15). Replacement of 35% wheat in dry food by barley decreased protein digestibility by 7 %units and made stools more loose and moist. The effects were partly counteracted by spraying a mixture of beta-glucanase, xylanase and amylase onto the diet (16). Clearly, the diet contrasts in the digestibility trials (14-16) involved more than barley beta-glucans only.

Immunomodulatory concept

Various intestinal, innate immune cells have so-called pattern recognition receptors (PRRs) that may bind diet-derived beta-glucans, just as they do with beta-1,3-glucans in cell walls of certain pathogenic yeasts, fungi and bacteria. Receptor binding signals phagocytosis and pathogen degradation by the leukocytes of the innate immune system. Leukocytes also release cytokines and antigens that stimulate antibody production by the adaptive immune system. The altered cytokine profile may protect against inflammation.

Dietary beta-glucans act as immunomodulator only if quantity and structure are effective on their arrival at the intestinal, innate immune cells. Beta-glucans of higher purity are active, unlike beta-glucans embedded in (partially digested) food ingredients. PPRs are highly specific for pure β-(1, 3) backbone structures (17).

Immune indicators

Oral administration of purified beta-glucans from yeast or oyster mushroom enhanced antigen-induced immune responses. Dogs were injected with ovalbumin (10, 18) or vaccinated against rabies plus parvovirus (19-21) and bordetella (22). In-vitro phagocytosis, as index of the innate immune system, was quantified as leukocyte percentages with internalized polystyrene beads. Serum levels of specific antibodies against the antigens served as measure of the adaptive immune system.

The equivalent of 0.08% purified beta-glucans in dry food stimulated phagocytosis by 43% and induced a 3.36-fold increase in specific antibodies. These mean effects concern 3 to 10 weeks post-antigen injection and four studies (10, 18-22, Note 2).

Inflammatory diseases

In double-blinded, placebo-controlled trials, lasting 8 weeks, dogs with osteoarthritis (n = 23/group) or atopic dermatitis (n = 15 or 16) received dry food without or with 0.08% of a purified yeast beta-glucan preparation (23, 24). Beta-glucan treatment improved owner-assessed severity scores of arthritis and atopy by 79 and 63%. In dogs (n = 7) with inflammatory bowel disease, feeding dry food without or with 0.05% purified yeast beta-glucan for six weeks changed the clinical index (scale 0-18) from 5.8 to 7.1 or 6.0 to 0.9 (25). Reproducibility is unknown for each trial.

Note 1

Analysed amounts (g/100 g) of total water-soluble beta-glucans
in cereal grains and dried yeast

Ref	Corn	Rice	Barley	Wheat	Oat	Yeast*
1			5.1[5]			
2		0.6[2]	2.9[2]	0.7[2]	2.1[2]	
3			3.4[2]			
4	1.0[2]		3.6[1]	0.8[1]	4.1[1]	
5	0.9	0.7	3.9	0.8	4.8	
6						17.0
7						8.5
8						11.0
9						8.0
Mean^	1.0	0.7	3.8	0.8	3.7	11.1

^Overall mean. *Spent dried yeast (*Saccharomyces cerevisiae*)

Within references, beta-glucan levels are means for the number of cereal varieties as indicated by superscripts. Means for two husked and dehusked barley varieties were 5.0 and 4.8% (1). Reference 5 gives lowest and highest values for an undisclosed number of cereal species; the means are presented here. The article (5) also displays various literature values.

Yeast beta-glucan was calculated as residual fraction (6), measured enzymatically as beta-1,3/1,6-glucan (7, 9) or analysed in cell walls by polysaccharide hydrolysis followed by high performance anion-exchange chromatography (8).

Note 2

Impact of orally administered beta-glucans on immune responses in antigen-treated dogs. The innate and adaptive responses are represented by in-vitro phagocytosis of leukocytes and serum levels of antigen-specific antibodies; beta-glucan effects are expressed as multiplier of the corresponding control values

Ref	Betaglucan*		Anti-gen+	n	Day	Innate response √		Adaptive response $	
	Prep	Diet%				Phagocytosis		Antibody level	
10, 18	1	0.10[1]	a	5	28	1.29[1]	1.19[2]	8.75[4]	
,,	2	0.17[2]	,,	,,	,,	1.69[1]	1.71[2]	5.13[4]	
19, 20	3	0.02[3]	b	24	56	1.02[3]		2.67[5]	1.87[6]
21	4	0.01[4]	c	15	56	1.70[3]		1.25[5]	2.61[6]
22	5	0.08[5]	d	5	28			1.21[7]	
Mean		0.08				1.43		3.36	

All studies had a parallel design with equal number of dogs (n) per treatment. Day refers to the moment of blood sampling or to the means of days 42, 56 and 70 (20) or 21, 28 and 35 (22).

*Betaglucan preparation: 1,2, *Saccharomyces cerevisiae* fraction containing 77 or 56% beta-glucans; 3, fraction from oyster mushroom (*Pleurotus ostereatus*) in syrup form (Plerasan V; Pleuran, Bratislava) containing 10 mg beta-1,3/1,6-glucans per ml (26); 4, fraction from oyster mushroom in syrup form (VET-P-IM; Pleuran, Bratislava) containing 10 mg beta-1,3/1,6-glucans per ml; 5, tablets (MacroGard, Biorigin, São Paulo) each containing 100 mg beta-1,3/1,6-glucan from *Saccharomyces cerevisiae*.

*Betaglucan, diet%: [1,2]oral doses were 15 or 25 mg/kg body weight per day. At an intake of 15 g dry food/kg body weight per day, the dietary concentrations would be 100 and 167 mg/100 g; [3]dogs aged 4 months received 2 ml Plerasan V/5 kg body weight per day; the equivalent dietary concentration would be 18 mg/100 g for a dry food intake of 22.5 g/kg body weight per day; [4]beta-1,3/1,6-glucan was administered to 6-weeks old dogs at a dose of 4 mg/kg body weight per day, which would be 13 mg/100 g for dry food intake at 30 g/kg body weight per day; [5]Female Beagles were given orally 150 mg beta-1,3/1,6-glucan per day. For an assumed body weight of 12 kg and dry food intake of 15 g/kg body weight per day, the dietary equivalent is 83 mg beta-glucans/100 g.

+ Antigen: a, ovalbumin, injected subcutaneously on Days 7 and 21; b, polyvalent vaccine, including canine parvovirus, was administered on Days 1 and 14 and rabies vaccine on Day 28; c, polyvalent vaccine, including canine parvovirus type 2, was injected on Days 0, 21 and 42; on Day 42, the dogs were vaccinated against rabies virus also; d, on Days 14 and 28, dogs were vaccinated subcutaneously with inactivated *Bordetella bronchiseptica* and parainfluenza virus type 2.

√ Innate immune response: in-vitro phagocytosis of 2-hydroxyethyl metacrylate by monocytes[1], neutrophils[2] and total leukocytes[3], expressed as percentage of positive cells.

$ Adaptive immune response: [4] level of serum antibodies against ovalbumin; [5]level of antibodies against rabies; [6]level of antibodies against canine parvovirus; [7]serum level of Bordetella specific immunoglobulin M.

Note 3

Indicators of the innate immune response other than phagocytosis have also been measured. A study presented in the table of Note 2 (10, 18) found that oral administration of two preparations of yeast beta-glucans raised the serum levels of interleukin 2 by multiplier factors as huge as 185 and 111. In another study (19, 20), ingestion of oyster-mushroom beta-glucans did not affect chemotactic activity of polymorphonuclears and the mitogen-induced blastogenic response of blood lymphocytes, the multiplier factors being 1.04 each. As indicator of the adaptive immune response, the antigen-induced level of serum total immunoglobulin G was left unchanged after oral intake of yeast beta-glucans; the multiplier factor was 1.00 (22).

Oral yeast beta-glucans did not affect the serum levels of total immunoglobulins A and M in dogs unchallenged with antigen; the multiplier factors were 0.95 and 1.02 (22). Unchallenged dogs, aged 6-12 months, received capsules (Imuneks, Mustafa Nevzat Drug Company, Turkey) containing 10 mg beta-1,3/1,6-glucan from *Saccharomyces cerevisiae* (27, 28). The beta-glucans were administered at a dose of 3 mg/kg body weight per day, which is equivalent to 13 mg/100 dry food, or 0.01%. After 14 days, blood cells and serum immunoglobulins were quantified in control and glucan-fed dogs (n=4/group). Feeding yeast beta-glucans did neither influence the counts of blood neutrophils and lymphocytes nor the serum levels of immunoglobulins A, M and G. The multiplier factors were 1.01, 0.95, 1.02, 1.18 and 1.07. For monocyte counts, the factor was 0.69.

Note 4

As described above, oral administration of purified beta-glucans from yeast (*Saccharomyces cerevisiae*) and oyster mushroom (*Pleurotus ostereatus*) have been demonstrated to influence the antigen-challenged immune system of dogs (10, 18-22). In one study with mice, both the feeding of purified yeast and barley glucans had immunomodulatory activity (29). Other mouse experiments showed immune stimulation by ingested purified beta-glucans from oat (30) or a plant pathogenic fungus (*Sclerotinia sclerotiorum*) (31). Intravenously injected beta-glucans from shiitake mushroom (*Lentinula edodes*) also affected the immune system in mice (32).

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