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Review Article

SUPPLEMENTATION OF NSPASE IN FULL-FAT SOYBEAN-BASED DIETS IN BROILER CHICKEN

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Abstract: *The present study aimed to assess the impact of incorporating commercially available non-starch polysaccharide enzyme (NSPase) in soybean meal (SBM) and full-fat soybean-based diets on broiler bird development, nutritional digestibility, and gut health. Feed costs account for a significant portion, up to 70%, of overall production expenses in poultry businesses. Broiler diets predominantly consist of cereal grains containing varying levels of non-starch polysaccharides (NSPs), a fibrous component. NSPs in broiler diets hampers overall performance by reducing nutrient absorption due to increased digesta viscosity, thereby decreasing feed efficiency. It is estimated that 400-450 kcal/kg of feed remains unmetabolized in broilers fed a standard corn-soy diet. Exogenous enzymes function by making previously indigestible substances accessible for digestion by endogenous enzymes. NSPase enzyme has the potential to enhance digestion by reducing viscosity and releasing energy through the breakdown of undigested feed components.*

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Introduction

Soybean meal is an important ingredient and desired-quality protein source for poultry feed. It contains a high CP concentration of 43 to 50% and a well-balanced amino acid (AA) profile. Soybean meal is a source of essential amino acids (EAA) for poultry birds' normal growth and development. In chicken diets, a percentage of inclusion of 25 to 40% is employed. Soybean meal constitutes around 30% carbohydrates, with 20% being NSP and 10% being oligosaccharides (Hollung et al., 2006). So, to ensure the availability of these 20% NSP, the NSPase enzyme is being used in the corn-soy-based diets of broilers.

The poultry sector is one of the major users of exogenous enzymes. The highly interconnected structure has aided the acceptance of new knowledge, and the use of NSPases has become a requirement to increase digestibility and nutrient use efficacy. The addition of enzymes in poultry feed aims to enhance bird performance and cost-effectiveness by improving dietary nutrient digestion. The introduction of enzymes expands the variety of feed constituents that may be used and enhances feed formulation versatility. The variation in nutritional value between batches of components is decreased by exogenous enzyme inoculation, allowing for a more precise diet design. Exogenous enzymes affect international chicken production regarding environmental effects, bird well-being, intestinal health, sustainability, and enhanced nutrient digestion.In the poultry business, enzymes are frequently utilized to break down anti-nutrients, which release bound nutrients and increase the amount of nutrition available to the bird. Among other advantages, this can save feed costs by giving poultry diets more alternatives for sustainable foods (Khattak et al., 2006). According to Khatak et al. (2006), some microorganisms like fungi, bacteria, or yeast are typically used to create feed enzymes. When adding exogenous enzymes to broiler diets, dietary energy (E) can be decreased by replacing fat with maize or diluting it with fiber. A reduction in dietary energy harms broiler performance (Maseyy O'Neil et al., 2012). However, supplementing NSPase in low-energy diets improves body weight gain and FCR (Rehman et al., 2016). NSP-degrading enzymes, such as xylanase, can be added to the diet to enhance energy consumption, resulting in lower dietary costs and improved FCR (Masey O Neill et al., 2012). Dietry supplementation of NSPase improves the overall performance of broiler chickens in an SBM-based diet by promoting gut health resulting in more precise animal performance and increasing the digestibility of the feed (Kiarie et al., 2013).

Non starch polysaccharides

A significant quantity of dietary NSPs may be found in all vegetative feedstuffs. The most common ingredient in poultry rations is soybean meal and Corn, which have variable amounts of NSPs. Some of the most important NSPs in SBM include galactomannans, pentosans, arabinoxylan, arabinogalactans, glucans, mannans, xylans, oligosaccharides, pectins, and cellulose (Bacic et al., 1988; Choct, 2006). According to Irish and Balnave (1993), soybean meal contains 16% insoluble NSP and 3% soluble NSP. Sticky excreta is one of the elements that cause floor-raised broiler footpad sores. In terms of nutrition, this problem is brought on by excessive intestinal viscosity brought on by dietary intakes of soluble NSPs.

Exogenous enzymes in poultry diets

Efficient, cost-effective, and thermostable enzymes should be used. Enzymes are proteins; temperatures above 80°C during pelleting can cause them to lose their effectiveness or degrade (Silversides and Bedford, 1999). To maintain enzyme effectiveness during feed production, preventative measures such as external coatings and naturally thermophilic enzymes should be considered (Gilbert and Cooney, 2010). Please ensure enzymes selected based on substrates in the components used in ration formulations benefit most from their inclusion.

Non starch polysaccharide degrading enzymes (NSPase)

Exogenous enzymes can enhance the degradability of maize and SBM-based rations in various ways. Exogenous enzymes break down carbohydrates, proteins, and minerals encapsulated in polysaccharides. Exogenous enzymes make substances previously unavailable for digestion by endogenous enzymes available for digestion (Bedford and Morgan, 1996). The majority of the energy in cereal grains comes from starch. Starch is retained intracellularly and is partially unavailable to fowl without exogenous enzymes to break down cell wall components. To reduce the effect of cell wall's hiding nutrients, effective combinations of NSP-degrading enzymes could be used, enhancing starch, protein, and energy consumption. Preparations of multi-enzyme in feed increase fiber digestibility in feed components by targeting several substrates (Alagawany et al., 2018).).

Table 1. Effect of enzyme supplementation on broiler performance and nutrient digestibility

Age of birds (Days)	Product	Dose Rate	Enzyme activities	Result Reported			Reference
				Parameters	Control	Treated	
1-42	Vitazyme	25g/kg	β-glucanase, Xylanase, Cellulase, Protease	FI: * BWG: * FCR:*	3125 g 1650 g 1.89	3317 g 1711 g 1.93	Anjum (2005)
0-42	Rovabio	500g/ton	β-glucanase, Xylanase, Cellulase, Pectinase, Protease	FI: NS BWG: NS FCR: NS	4555g 1971g 2.31	4905g 2042g 2.40	Nadeem *et al.* (2005)
5-18		1000g/ton	Cellulase, Pectinase	FI: * BWG: * FCR: *	668 g 436 g 1.53	687 g 459 g 1.50	Meng *et al.*(2005)
7-42		1000g/ton	Xylanases, β-glucanases	FCR: ** ADG: **	2.08 52.32 g	1.99 54.90 g	Wang *et al.* (2005)
0-28	Roxazyme® VP	2000g/ton	β-glucanase	FI: NS BW: * FCR: *	2274 g 1161 g 2.29	2306 g 1214 g 2.11	Centeno *et al.* (2006)
3-42	Rovabio ™	3000ml/kg	Xylanase, β-glucanase, Cellulases	FI: NS BW: * FCR:*	3088 g 1611 g 1.91	3247 g 1644 g 1.97	Haroon, (2006)
22-42	Rovabio Excel AP 10%	500g/ton	Xylanase, β-Glucanase	FI: NS BWG: NS FCR: NS	915g 424g 2.16	918g 428 2.15	Mushtaq *et al.* (2007)

0-35	Roxazyme G®	2000g/ton	Glucanase, Cellulase, Xylanase	FI: NS BWG: NS FCR: NS	101g 18.79g 2.67	103g 20.77g 2.65	Omojola *et al.* (2007)
1-31	Rovabio™ Excel	220g/ton	Xylanase, β-Glucanase	BWG: NS FCR: NS	1551g 1.70	1538g 1.72	West *et al*. (2007)
8-21	Allzyme	1000×XU/kg	Xylanase	FI: NS BWG: * FCR: * CP Dig NS	1354g 740g 1.83 68	1304g 797g 1.65 73	Yang *et al.* (2008)
0-21	Bergazym P®	250g/ton	Xylanase, β-glucanase, α-amylase, Galactomannase	FI: NS BWG: NS FCR: NS	828.5g 572.2g 1.57	840.6g 539.4g 1.70	Zakariya *et al*. (2008)
1-35	Rovabio Excel	500g/ton	Xylanase, β-glucanase, Mannanase, Cellulases	FI: * BWG: * FCR: *	2942g 1379g 2.14	3000g 1374g 2.17	Aftab *et al*. (2009)
1-42		500g/ton	Xylanase, β-glucanase	FI: * BW: * FCR: *	4082g 1964g 2.08	4211g 2291g 1.84	Shirzadi *et al.* (2009)
1-21	Rovabio Excel AP 10%	500g/ton	Xylanase, β-Glucanase	FI: BWG: *	943g 428g	938g 427g	Mushtaq *et al.* (2009)
1-32	Rovabio® Max	200ml/kg	Xylanase, β-Glucanase	FI: NS BW: * FCR: NS	85.4g 1778.4g 1.57	86.6g 1868.2g 1.51	Lee *et al*. (2010)
0-42	Rovabio™ Excel	500g/ton	Xylanase, β-glucanase, Mannanase Pectinase	FI: NS BWG: * FCR: NS	4456g 2203g 2.03	4624g 2323g 2.00	Rahmatnejad et al. (2011)
0-21	Rovabio Max™	200g/ton	Xylanase, β-glucanase, Mannanase	BWG: * FCR: *	823g 1.55	887g 1.57	Min et al. (2011)
1-42	Rovabio Max®	100g/ton	Xylanase, β-glucanase, Mannanase, Pectinase, α-galactosidases	FI: BWG:* FCR: *	4653.6g 2553.3g 1.82	4699.9g 2620.1g 1.79	Neto et al. (2012)
0-21		100g/ton	α-galactosidases	BWG: * BW:	774.1g 816.5g	803.3g 845.7g	Zou et al. (2013)
14-25	Pectinex Ultrasp-L, Pectinase FE	25ml/kg	Pectinase, Hemicellulase	ADFI: NS ADG: NS FCR	81.3g 64.1g 1.27	81.1g 62.4g 1.31	De Vries et al. (2014b)
21-42	Rovabio Excel AP	500g/ton	Xylanase, β-glucanase	FI: NS BWG: FCR:	4029g 2022g 1.99	4068g 2067g 1.96	De Araujo et al. (2014)
1-21	Enspira	113.5g/ton	Xylanase, β-glucanase, α-galactosidase	BWG FCR	754.4g 1.52	761g 1.53	Campsion *et al*., (2015)
14-25	Pectinex Ultrasp-L, Pectinase FE	25ml/kg	Pectinase, Hemicellulase	ADFI: NS ADG: NS FCR	81.3g 64.1g 1.27	81.1g 62.4g 1.31	De Vries et al. (2014b)
21-42	Rovabio Excel AP	500g/ton	Xylanase, β-glucanase	FI: NS BWG: FCR:	4029g 2022g 1.99	4068g 2067g 1.96	De Araujo et al. (2014)
1-21	Enspira	113.5g/ton	Xylanase, β-glucanase, α-galactosidase	BWG FCR	754.4g 1.52	761g 1.53	Campsion *et al*., (2015)
14-42		500g/ton	Cellulase, β-glucanase, Xylanase	FI BWG FCR	3970g 2149g 1.85	3992g 2134g 1.87	Horvatovic *et al*., (2015)

1-28	Cocktail	400g/ton	β-mannanase Xylanase β-glucanase α-galactosidase	BWG FCR	1606g 1.45	1590g 1.46	Klein *et a*l., (2015)
1-21		250 U/kg	β-glucanase, Xylanase	FI BWG FCR CP dig	993g 789g 1.26 75.5	942g 831g 1.13 76	Munyaka *et al*., (2016)
1-39		113.5g/ton	Xylanase, β-glucanase, α-galactosidase Amylase	FI BWG FCR	4329g 2817g 1.63	4394g 2823g 1.64	Allcorn (2016)
1-42	Zympex 008	500g/ton	α-galactosidase, β-mannanase, Protease, Amylase, β-glucanase, Xylanase, Cellulase.	FI BWG FCR CP dig.	3067g 1567g 1.95 71.36	2940g 1573g 1.88 72.56	Bilal *et al*., (2017)
1-42	Rovabio Kamin	250g/ton 500g/ton	ß-glucanase Cellulase β-xylanase, α-amylase	FI BWG FCR	4606.8g 2396.9g 1.93	4859.1g 2716.1g 1.790	Hashemi *et a*l., (2017)
1-28	Endopower	500g/ton	Galactomannanase, Xylanase, β-glucanase, α-galactosidase	FI BWG FCR	2102g 1417g 1.48	2101g 1446g 1.45	Mohammadigheisar *et al*., (2018)
1-42		113.5 g/ton	Xylanase ß-glucanase, α- galactosidase	BWG FCR	2620g 1.701	2707g 1.71	Walters *et al*., (2018)
1-45		100g/ton	Xylanase ß-mannanase	BWG FCR	2950g 1.81	2960g 1.82	
15-21	Ronozyme Multigrain	75 g/ton	Xylanase, Cellulase, β-glucanase	DM dig. CP dig.	65.7 79.3	74.8 86.0	Woyengo *et al*., (2019)
1-38	Galzym-M	200g/ton	Cellulase, 4-β-xylanase, α-amylase,	BWG	1844g	2079g	Attia *et al*., (2020)
24-28		1500 EPU/kg	endo-glucanase endo-xylanase	DFI ADG CP dig	123.3g/d 76.4g/d 76.99	130.2g/d 86.1g/d 81.17	Kouzounis *et al*., (2021)
1-35	Rovabio Advance T	500g/ton	Phytase ß-xylanase	FI BWG FCR	3,730.9g 2,313.1g 1.60	3,772.1g 2,362.7g 1.589	Poernama *et al*., (2021)
1-37		100g/ton	ß-xylanase	FI BWG FCR	4229.7g 2728.7g 1.55	4288.6g 2739.4g 1.566	Saeton *et a*l., (2021)

FI = Feed Intake, ADFI = Average Daily Feed Intake, BW = Body Weight, BWG = Body Weight Gain, ADG = Average Daily Gain, FCR = Feed Conversion Ratio,

GE = Gross Energy, AME = Apparent Metabolizable Energy, CF = Crude Fiber, CP = Crude Protein, Dig = Digestibility, NS = Non-Significant, $P<0.05$ = *,

Nutritional profile of SBM and full-fat soybean

Any variation in soybean processing necessitates verifying the meal's capacity to resist growth performance comparable to solvent-extracted SBM. Defatted soybean has a protein digestibility of 65.4 percent (Zahran, 2000). It was enhanced by increasing the extrusion temperature during the extrusion process. The capability of poultry to completely utilize the nutrient constituents of soybeans relies on the processing method used to yield the meal.

Table 2. Nutritional profile of full-fat soybean

Nutrient (%)	**Erdaw, *et al*. (2017a)**	**Rocha *et al.* (2014)**	**Erdaw, *et al.* (2017a)**	**Ari *et al.* (2017)**
Dry matter	92.5	92.4	91.05	92.36
ME (kcal/kg)	3393	-	3357	-
Crude fiber	5.19	6.2	3.57	3.9
Crude fat	18.8	18.5	20.7	18
CP	37.3	38.2	36.87	38.02
Lysine	2.32	2.66	2.27	2.19
Methionine	0.50	0.56	-	0.48
Cysteine	0.58	0.60	0.49	0.56
Arginine	2.67	3.29	2.81	2.60
Histidine	0.96	1.09	0.99	0.97
Valine	1.77	1.87	1.77	1.67
Isoleucine	1.71	1.79	1.65	1.61
Leucine	2.86	3.1	3.10	2.71
Threonine	1.44	1.61	1.34	1.37
Phenylalanine	1.89	1.73	1.80	1.79
Tryptophan	0.51	0.47	-	0.48

Soybean components and anti-nutritional factors

Soybean seeds contain, on average, 21% oil, 40% protein, and 35% carbohydrates (Liu, 1997).

Carbohydrates

In general, the metabolizable energy of soybeans in poultry is much lesser than its gross energy (GE), which may be due to the inadequate digestibility of the carbohydrate portion (Coon *et al*., 1990; Pierson *et al*., 1980). Soybean carbohydrates are present in various forms, including glycolipids, monosaccharides, polysaccharides, oligosaccharides, saponins, sterol glucosides, and isoflavones (Eldridge *et al*., 1979). Most of these carbohydrate structures pose little risk to monogastric digestibility, except for oligosaccharides.

Oligosaccharides

Oligosaccharides are low molecular weight molecules comprised of less than ten monosaccharide residues connected by glycosidic linkages. They, along with sucrose, comprise over 99% of the sugars in the whole soybean (Hymowitz *et al*., 1972). Raffinose and stachyose, both soluble α-galacto-oligosaccharides, are highly concentrated in traditional soybean cultivars compared to other legumes (Rackis, 1975); and, when exposed to typical processing conditions, maintain their structure (Zdunczyk *et al*., 2011). Monogastric animals lack the α -galactosidase in the small intestine, which breaks down the α-1,6 galactosyl linkages (Graham *et al*., 2002). If the small intestine lacks the necessary digesting enzymes, the undigested oligosaccharide molecules accumulate in the large intestine. Exposure to anaerobic microorganisms and subsequent fermentation produces short-chain fatty acids and gas (Karr-Lilienthal *et al*., 2005).

Storage Proteins

Storage proteins, mostly consisting of globulins, account for the majority of protein in soybeans. Glycinin and α-conglycinin account for approximately 80% of these storage proteins (Moriyama *et al*., 2004), which, in turn, compromise more than 65% of the total protein in the soybean (Delwiche *et al*., 2007). Zhao (2008) suggested that most of the antigenic effects observed with soy proteins should be attributed to α-conglycinin due to increased resistance to proteolytic enzymes compared to other soy proteins. α-conglycinin was more susceptible to heat than glycinin (Castro, 2014).

Lectin

Soy lectins are carbohydrate-binding glycoproteins with a preference for N-acetyl-D-glucosamine and D-galactose at the terminal (Schulze *et al*., 1995). Based on the denaturation degree, they can be categorized as agglutinating or non-agglutinating (Irish *et al*., 1999). Non-agglutinating lectins are partially denatured and have a single carbohydrate-binding site, whereas agglutinating lectins are non-denatured and have a quaternary structure with numerous carbohydrate-binding sites (Fasina *et al*., 2006). Lectins are sometimes called hemagglutinin due to their binding capabilities with erythrocytes of higher species. Undigested lectins bind to the erythrocytes along the membrane of the intestine, damaging morphology and disrupting normal nutrient absorption (Pusztai, 1994). Intestinal enterocyte damage is the primary cause of growth depression in monogastric-fed high lectin levels (Pusztai *et al*., 1979).

Contrary, Fasina *et al*. (2006) demonstrated enhanced intestinal development in turkeys fed semi-purified feed augmented with low or high levels of lectin. They cited the intestine's ability to adapt to dietary changes by altering the length, absorbent area, and rate of enterocyte turnover as a possible explanation. Though an increased villus crypt ratio was reported, Fasina *et al.* (2006) did recognize the harmful effects of soy lectin on lymphoid organs, indicating that lectins may lead to a compromised immune system. It was reported that soy lectin reduced the growth performance of chicks, though to a lesser extent than trypsin inhibitors (Douglas *et al*., 1999). Lectin levels can be decreased or removed by heating (Vasconcelos and Oliveira, 2004) or genetic selection (Palacios *et al*., 2004).

Protease Inhibitors

Trypsin inhibitors are a group of serine proteases researched extensively and shown to disrupt digestive enzymes and reduce soybean nutrient utilization in poultry, swine, and mice (Kunitz, 1944). Studies have indicated that trypsin inhibitor is not fully responsible for pancreatic hypertrophy. Rats fed an inhibitor-free soybean extract still had suppressed growth and enlarged pancreas weights Kakade (1973). In subsequent *in-vitro* degradation studies, the authors concluded that trypsin inhibitors take up only 40% of growth retardation in raw soybeans, with other anti-nutritional factors accounting for the remaining 60%.

Effect of NSPase on

Growth performance

Alam *et al*. (2003) reported that feed consumption, live weight, profitability, and dressing yield could be improved by using enzymes in the diets of the broiler. Adding enzymes could reverse NSP's antinutritive effects on broiler growth performance (Alam *et al*., 2003). NSPase supplementation in maize-soybean-based diets decreased FCR by up to 5% in the starter and grower diets, but there was no impact in the finishing phase (Coppedge *et al*., 2011). The experimental dietary trial demonstrated by Esmaelipour *et al*. (2011) supplementation of exogenous enzyme (xylanase) enhanced feed conversion ratio by 3 to 6 points between days 15 and 23. Several other studies have demonstrated that adding xylanase to the diet improves FCR (Gao *et al*., 2007). The FCR and BWG were improved with wheat and barley-based meals, along with maize and SBM-based diet (Copedge *et al*., 2012; Esmaeilipour *et al*., 2011).

With the usage of xylanase, improvements in FCR might be attributed to improved dietary nutrient utilization. Esmaelipour *et al*. (2011) investigated that supplementing with xylanase increased CP, DM, and energy retention. Kalmendal and Teuson (2012) reported that adding xylanase to the diet improved energy retention and increased AMEn levels. According to Coppedge *et al*. (2011), adding xylanase to a diet helped some authors overcome energy losses. Adding xylanase to the diet improved performance by decreasing AME by 132 kcal/kg; it's possible that supplementing the feed with xylanase enhances broiler growth performance, nutrient digestibility, and utilization. Lowered mannan content in the stomach reduced energy expenditure by activating the innate immune system, resulting in more effective feed utilization and energy expenditure, according to Jackson *et al*. (2004). Meng *et al*. (2005) supplemented a multi-carbohydrase comprising 1000 IU xylanase, 400 IU glucanase, 1000 IU pectinase, and trace quantities of cellulose, manganese, and galactanase to broilers aged 5 to 18 days and reported enhancement in FCR. Meng and Slominski (2005) reared broiler birds in a cage system from days 5-18 old and offered various enzyme preparations comprising xylanase, glucanase, cellulase, mannanase, and pectinase, and showed that by addition of enzymes in different diets resulted in increased body weight gain. Coppedge *et al*. (2011) discovered that adding an NSPase supplement to maize and SBM-based diets improved BW and FCR. According to Cowieson and Ravindran (2008), adding multi-enzyme preparations to maize- and SBM-based diets enhanced DM retention, AME, and apparent ileal digestibility percentage of DM and nitrogen. The addition of the carbohydrase/phytase enzyme at 0.075 g/kg enhanced growth efficiency and apparent ileal digestibility of DM, and nitrogen, particularly during the developing period, on a corn-soybean-based ratio that was rather low in energy (Lu *et al*., 2013). Exogenous enzyme supplementation (mannanase, endo-xylanases, and galactosidase) increased the FCR of broilers by enhancing energy metabolism and digestive physiology (Zou *et al*., 2013). Reduced dietary energy had a detrimental influence on broiler performance, resulting in a rise in FCR and a drop in fat pad output; however, these effects were mitigated by adding xylanase to the feed (Williams *et al*., 2014). During the starter stage, xylanase supplementation improved feed efficiency in broiler chickens; when compared to mash diets, the response of birds was steadier and more measurable in pelleted or crumbled diets with xylanase supplementation (Barasch, 2015). Broiler growth performance was improved by dietary mannanase, which increased the maintenance of gross energy, soluble and insoluble NSP (Hosseindoust *et al.*, 2018). NSP-degrading enzymes with less energy allowed for full recovery of broiler growth and improved economic parameters. Enzyme supplementation increased production but had little impact on mortality or litter composition. Furthermore, future investigations using fecal or digesta collection might repeat this technique to understand further the effect of enzyme supplementation on chicken gastrointestinal flora (Chalghoumi *et al*., 2020).

Contrary, Olukosi *et al*. (2010) demonstrated that broiler performance was unaffected by adding multi-enzymes (amylase, xylanase, and protease) to diets based on maize and SBM or on diets having distillers' dry grains with solubles. Erdaw *et al*. (2017) reported broiler growth performance by fed raw full-fat soybean and protease-fortified diets. Three levels of SBM were substituted with full-fat soybean at 0, 10, and 20%, as well as protease (0.1, 0.2, or 0.3 g/Kg). All treatment was repeated six times, with each duplicate having nine birds. The birds were fed three diets: starter, grower, and finisher. Birds' body weight was lowered early, and raw full-fat soybean supplementation had no significant effect on BWG at 35 days of age ($P>0.05$). During the whole time, neither raw-full-fat soybean nor protease addition in diets significantly affected broiler weight gain (0 to 35 days). It was proposed that up to 20% of SBM might be interchanged with raw, full-fat soybean for broilers. In comparison to the control group, raw full-fat soybean resulted in a significant reduction in body weight. Compared with a control group, the body weight of birds given raw full-fat soybean at 12% was considerably reduced. Although the difference was not significant when broilers fed raw full-fat soybean l, 4 and 8% of their body weight compared to controls. Heger *et al*. (2016) investigated the impact of different processing methods on full-fat soybean (FFSB) growth parameters in meat-type birds, replacing SBM at 40%, 38%, 36%, and 34% in broiler diets. In 38% of the replaced diets, higher feed intake (FI) was reported. Short-term (120°C for 15 seconds) and long-term (100°C for 5 minutes) conditioning produced the best results regarding body weight gain. Non-significant results were observed across the treatments. It was reported that FCR during starter, grower, finisher, and overall experimental phases was better in birds fed a diet containing full-fat soybean obtained using short-term (120°C for 15s) and long-term (100°C for 5 minutes) conditioning processes. However, non-significant results were observed in all other treatments.

In the feed of broilers, Mirghelenj *et al*. (2013) employed four different amounts of extruded full-fat soybean (0, 7, 15, and 22.5 percent) instead of de-hulled SBM and soy oil. Dietary interventions did not significantly influence intake during the beginning phase (days 0-14). Broilers were given a diet containing 22.5% extruded full-fat soybean and had the lowest (P0.05) feed consumption throughout the finisher phase (days 29-42). From the first 42 days, birds fed a meal containing 22.5 percent extruded full-fat soybean gained less weight than control chicks. On the other hand, for birds that were fed meals containing 15% extruded full-fat soybean, weight growth was unaffected. In the starter grower and finisher, no group influenced FCR. Onwumelu *et al*. (2012) investigated the effects of substituting full-fat soybean in broiler bird diets with raw soybean treated with a graded quantity of yeast. Fifteen diets were created by substituting SBM with full-fat soybean @ 0% (control), 25%, 50%, 75%, and 100%, with three degrees of yeast treatment and no yeast treatment as a control. According to the findings, birds fed a meal comprising 75 percent full-fat soybean, 25 percent raw soybean, and 8 g/kg yeast had increased feed consumption. Birds given 100 percent SBM with 12g yeast had the lowest feed consumption. According to the findings, birds fed a meal comprising 75 percent full-fat soybean, 25 percent raw soybean, and 8 g/kg yeast gained higher weight. Birds given 100 percent SBM with 12 grams of yeast gained less weight. The best FCR was found in birds fed a meal comprising 75 percent full-fat soybean, 25 percent raw soybean, and 8 g/kg yeast. Zhaleh *et al.* (2012) investigated the impact of different amounts of extruded full-fat soybeans on broiler performance from days 0 to 42. Two hundred and forty (250) day-old male Ross-308 chicks were assigned to 24 pens. In a 2x3 factorial design, six starters, growers, and finishers experimental diets were developed, with two dietary amounts of extruded full-fat soybeans (7.5 and 15%) and three extrusion temperatures (145, 155, and 165°C for 15 sec). During the starter, grower, and finisher stages, the extrusion temperature showed no significant influence on intake. Increasing the amount of extruded full-fat soybean in the diet from 7.5 to 15% reduced feed intake and growth rate. Birds fed a diet containing 15% extruded full-fat soybean consumed less feed than those fed a diet containing 7.5% extruded full-fat soybean. Extrusion temperature did not influence body weight during the starter, grower, and finisher stages. The growth decreased when the percentage of extruded full-fat soybean in the diet was raised from 7.5 to 15%.

In an experiment, Al-Sardary (2010) examined the development capabilities of broilers that fed full-fat soybeans. Diets comprising 10, 20, and 30% of full-fat roasted soybeans, 20% unroasted soybeans, or a control diet containing SBM were developed. Five replicates of 30 chicks were fed a different diet for the beginning and end of each phase. All the experimental diets were reported to be similar regarding feed intake during the starter phase. During the finishing phase, the control group showed a significant difference in intake than all others but comparable to the group-fed diet containing 10% roasted soybean. During the experiment, birds fed a diet containing 30% roasted full-fat soybeans had the lowest feed intake of all other groups. They reported higher weight gains and final body weights in the group fed SBM, 10 and 20% of roasted SBM, than 20% un-roasted full-fat soybean during the starter and finishing phases. The control group showed better FCR than birds fed roasted full-fat soybean as 30% in broilers' diet.

Popescu and Criste (2003) conducted an experiment to test diets based on full-fat soybean offered to broiler birds. Feed intake of broilers fed on a diet comprised of maize, SBM, fish meal, and full-fat soybean was not different among the treatments during starter, grower, and finisher groups. Subuh *et al.* (2002) studied whole unextracted soybeans and processed beans extruded through a roller mill without steam. The processed feed was given to male chicks in ratios of 0/100, 25/75, 50/50, and 0/100 percent in place of solvent-extracted SBM for 42 days. Similar body weight gain across all treatments was observed during starting and finishing phases. Diets containing 75 and 100 % full-fat soybean had higher weight gain than all other treatments. It was also reported that FCR was better in broilers fed 50% roasted full-fat soybean than control and un-roasted, but no improvement in FCR was observed beyond the 50% inclusion level of roasted full-fat soybean. During the finishing phase, birds fed diets containing 100% roasted full-fat soybean had better FCR than all other treatments.

Mateos and Salado (1999) conducted a series of experiments to find the optimal level of full-fat soybeans in a diet for the maximum growth of broilers. In the first trial, three treatment diets (SBM + oil, toasted full-fat soybean or extruded full-fat soybean at 20% of the diet). All diets were iso-caloric (3050 Kcal/kg for 1-20 days; 3250 Kcal/kg for 21-42 days) and iso-nutritive (1.25% total lysine for 1-20 days; 1.18% total lysine for 21-42 days). Results showed that all diets were the same *($P>0.05$)* for all growth performance parameters. The second study was conducted to find the effect of different fat sources (olive oil, soybean oil, and fish oil) on the growth of broilers. Different fats (5%) were added to the diet and fed to boilers from 1-20 and 21-42 days of age. The boilers' performance was reduced by using saturated fat in the diet. Diet having soybean oil showed the best weight gain and FCR results. The third experiment was conducted to check the influence of full-fat soybean collected from different sources. The result showed that weight gain was significantly *($P<0.05$)* affected by the source of full-fat soybean. On the other hand, intake and FCR remained unaffected. An experiment compared the effect of different sources of full-fat soybean with SBM + oil. Results revealed no difference in chick performance either at 7 or 21 days of age by feeding either type of diet. The last experiment studied the effect of soybean processing on the broiler's performance. Diets containing soybean processed through different methods (extruded full-fat soybean, cooked full-fat soybean, or SBM) were formulated and fed to boilers. Results of the trial demonstrated that broilers fed on a diet having extruded full-fat soybean showed improved intake and performance of the bird.

Nutrient digestibility

Exogenous enzyme products might be introduced to the maize-soy diet to boost the digestibility of starch in the intestine and increase energy utilization (Meng and Slominski, 2005). Esmaeilipour *et al*. (2011) reported that the xylanase supplement increases crude, dry, and energy retention. Kalmendal and Tauson (2012) noticed improved energy retention and increased AMEn by xylanase supplementation. They showed a significantly positive effect on the consumption of nutrients and performance. Enzymes in the diet improve energy and digestion of carbohydrates, raw proteins, starch, fat, and fibers (soluble and insoluble) (Cozannet *et al*., 2017). The addition of enzymes in rations improved nutrient digestibility, resulting in increased efficiency and performance. Furthermore, adding commercial enzymes to feed ingredients and diets boosted the nutritive value while allowing for more variety in diet formulation (Alagawany *et al*., 2018). Exogenous multi-enzyme supplementation (xylanases, ß-glucanases, pectinases, celluloses, and arabinofuranosidases) improved the nutritional value of the maize-soy diet by 3%, as it could pay costs for the 3% reduction in nutrients such as energy, protein, calcium, and phosphorus) through improved FCR (Kutlu *et al*., 2019).

Erdaw *et al*. (2017b) also observed decreased CP digestibility when raw full-fat soybean was added to the diet. Due to the high trypsin inhibitor (TI) in broiler diets, using untoasted full-fat soybean decreased CP digestibility (Palliyeguru *et al*., 2011). According to Rocha *et al*. (2014), anti-nutritional components in raw, full-fat soybeans compromise the intestinal epithelium's integrity and lower the digestion of nutrients. Toasting significantly increased FCR, demonstrated by CP's higher apparent ileal digestibility (Marsman *et al*., 1997). The CP and AA ileal digestibility was reduced when the raw full-fat soybean inclusion was increased. Overall pancreatic enzymes trypsin, chymotrypsin, and general proteolytic enzyme concentrations were also increased with protease supplementation in diets comprising raw full-fat soybean. Diets containing toasted full-fat soybean had average digestibility coefficients of 86.8%, 87.9 %, and 84.34 % for CP, essential AA, and non-essential AA, respectively. (MacIsaac *et al*., 2005). It enhanced CP digestibility by adding 4% processed full-fat soybean to chicken diets. Heat treatment of full-fat soybean improved amino acid digestibility in broiler diets.

The supplementation enhances the use of other nutrients in addition to energy. NSPase addition to an SFM-based diet enhanced the nutrient digestibility (Khan *et al*., 2006). Pourreza *et al*. (2007) assessed the impact of the inclusion of enzymes on broiler performance, protein, and dry matter degradability. In this investigation, triticale-based diets with various grades of enzymes were used. The addition of enzymes increased the apparent digestibility of both protein and energy. Broiler chicks fed a diet based on canola meal did not significantly benefit from the enzyme cocktail of glucanase and xylanase regarding nutritional digestibility (Mushtaq *et al*., 2007).

Gut morphology

Mehri *et al*. (2010) found that mannanase addition to corn-soy diets at 700 and 900 g/ton increased villus height and crypt depth in the duodenum. As the amount of dietary mannanase in the broiler diet increased, the viscosity of digesta in the ileum and the height of the villus in the jejunum increased linearly (Hosseindoust *et al*., 2018). Including an enzyme significantly affected the length of duodenum villi, which was likely to improve broiler growth efficiency, including body weight and FCR (Ravn *et al*., 2018). Including enzymes in less-energy feeds increased the expression of nutrient transporters, which enhanced micronutrient absorption and broiler growth efficiency (Saleh *et al*., 2018).

High poultry diets are insoluble NSPs that increase intestine viscosity, delay the digestibility of nutrients, and harm bird health and growth efficiency. The new generation of carbohydrates increases nutritional digestibility while reducing intestinal viscosity and competition in the small intestine between the host and microbiota, assisting in the absorption of a range of dietary fibers. It was also said to lower pathogenic microbe loads and increase intestinal health (Raza *et al*., 2019). According to Silversides and Bedford (1999), exogenous multienzyme cocktail supplementation in corn-SBM diets hypothesized that starch consumption in the proximal small intestine might increase if endogenous secretions and microbial flora have more time to act on nutrients.

Intestinal viscosity

Enzyme addition improved the production of broiler chickens fed fibrous diets, especially in the first four weeks of life. For broilers, the presence of NSPs causes various nutritional and digestibility issues that appear to be caused by too much viscosity (Svihus and Gullord, 2002). In broilers, higher intestinal density is frequently linked to slow transit rates, poor performance, and increased bacterial fermentation. (Annison, 1993). The beneficial result was linked to the decreased viscosity of broiler chickens feeding on supplemented enzyme diets. On the other hand, NSP negatively affects the digesta viscosity performance in diet (Steenfeldt *et al*., 1998). Dietary enrichment of NSPase, including phytase, decreased intestinal material viscosity by 12.2% and 16.6%. These findings indicate that NSPase that can break the cell wall matrix can help deliver encapsulated nutrients in cell walls and thus reduce viscosity, resulting in easier phytase exposure (Steenfeldt and Pettersson, 2001). Broilers with a low ME diet augmented with xylanase had lower digesta viscosity and better growth performance (Esmaeilipour *et al*., 2011). Another investigation used the xylanase at 100 g/kg feed and found that Ross 208 broilers given fiber diets gained substantially more body weight from 15 to 42 days (Engberg *et al.*, 2004). Enhanced diet components coupled with xylanase in the second trial may have stemmed in improved hydrolysis of soluble NSP and lower digesta viscosity, resulting in enhanced nutrient diffusion and energy availability required for better growth (Kocher *et al.*, 2002).

Conclusion

Supplementation of NSPase in low-energy diets improves body weight gain and feed conversion ratio (FCR). When exogenous enzymes are incorporated into broiler diets, dietary energy (E) can be reduced by substituting fat with maize or incorporating fiber.

Conflict of Interest

The authors declared no conflict of interest.

REFERENCES

Aftab, U., & Bedford, M. (2018). The use of NSP enzymes in poultry nutrition: myths and realities. *World's Poultry Science Journal* **74**, 277-286. https://doi.org/10.1017/S0043933918000272

Al-Sardary, S. (2010). Performance of broiler chickens fed locally grown fullfat soybean based diets in Iraq. *Iraqi J. Poult. Sci* **5**, 111-125. https://www.iasj.net/iasj/download/7a5780796059d6b4

Alagawany, M., Elnesr, S. S., & Farag, M. (2018). The role of exogenous enzymes in promoting growth and improving nutrient digestibility in poultry. *Iranian journal of veterinary research* **19**, 157. PMID: 30349560; PMCID: PMC6184034.

Alam, M., Howlider, M., Pramanik, M., & Haque, M. (2003). Effect of exogenous enzyme in diet on broiler performance. *International Journal of Poultry Science* **2**, 168-173. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=f3f7d626af27446115f1a2f14106190a6b3fd9b8

Allcorn, T. G. (2016). *Evaluation of exogenous enzyme combinations on broiler performance in reduced energy diets*. https://hdl.handle.net/1969.1/158603

Anjum, N. (2005). Effect of Vitazyme supplementation in high fiber broiler rations on the performance of broiler chicks. M.Sc. thesis. Inst. Anim. Nutr. Feed Technol. Univ. Agri. Faisalabad.

Annison, G. (1993). The role of wheat non-starch polysaccharides in broiler nutrition. *Australian journal of agricultural research* **44**, 405-422. https://doi.org/10.1071/AR9930405

Ari, M., Ayanwale, B., & Adama, T. (2017). Evaluation of different processing methods of soya beans (Glycine max) on its nutritive value and the performance of broilers: A qualitative selection approach for extension. *International Journal of Livestock Production* **8**, 113-124. https://doi.org/10.5897/IJLP2017.0371

Attia, Y., Al-Khalaifah, H., Abd El-Hamid, H., Al-Harthi, M., & El-Shafey, A. (2020). Effect of different levels of multienzymes on immune response, blood hematology and biochemistry, antioxidants status and organs histology of broiler chicks fed standard and low-density diets. *Frontiers in Veterinary Science* **6**, 510. https://doi.org/10.3389/fvets.2019.00510

Bacic, A., Harris, P. J., & Stone, B. A. (1988). Structure and function of plant cell walls. *The biochemistry of plants* **14**, 297-371.

Barasch, I. B. (2015). *The Evaluation of a Novel Heat-Stable Xylanase Supplemented to Broiler Chicken Diets*. North Carolina State University.

Bedford, M., & Morgan, A. (1996). The use of enzymes in poultry diets. *World's Poultry Science Journal* **52**, 61-68. https://doi.org/10.1079/WPS19960007

Bedford, M., & Partridge, G. (2010). Thermostability of feed enzymes and their practical application in the feed mill. *Enzymes in farm animal nutrition, Bedford MR, Partridge GG (eds). CABI, Oxfordshire, UK*, 368.

Bilal, M., Mirza, M., Kaleem, M., Saeed, M., Reyad-ul-ferdous, M., & Abd El-Hack, M. (2017). Significant effect of NSP-ase enzyme supplementation in sunflower meal-based diet on the growth and nutrient digestibility in broilers. *Journal of Animal Physiology and Animal Nutrition* **101**, 222-228. https://doi.org/10.1111/jpn.12552

Castro, M. D. L. M. (2014). Production of a Soybean Meal with High-Protein and Low Anti-Nutritional Factors for Fish Feed. https://scholarworks.uark.edu/etd/2369

Centeno, M. S., Ponte, P. I., Ribeiro, T., Prates, J. A., MA, L. F., Soares, M. C., Gilbert, H. J., & Fontes, C. M. (2006). Galactanases and mannanases improve the nutritive value of maize and soybean meal based diets for broiler chicks. *The Journal of Poultry Science* **43**, 344-350. https://doi.org/10.2141/jpsa.43.344

Chalghoumi, R., Mohamed, M., Alhazen, A., & Oakley, B. (2020). Evaluation of two commercial dietary enzyme products in broiler chicken fed reduced energy diets based on corn and soybean meal. *Large Animal Review* **26**, 31-

37. https://www.largeanimalreview.com/index.php/lar/article/view/87

Cho, J. H., Zhao, P., & Kim, I. H. (2012). Effects of emulsifier and multi-enzyme in different energy densitydiet on growth performance, blood profiles, and relative organ weight in broiler chickens. *Journal of agricultural science* **4**, 161. http://dx.doi.org/10.5539/jas.v4n10p161

Choct, M. (2006). Enzymes for the feed industry: past, present and future. *World's Poultry Science Journal* **62**, 5-16. https://doi.org/10.1079/WPS200480

Coon, C. N., Leske, K., Akavanichan, O., & Cheng, T. (1990). Effect of oligosaccharide-free soybean meal on true metabolizable energy and fiber digestion in adult roosters. *Poultry Science* **69**, 787-793. https://doi.org/10.3382/ps.0690787

Coppedge, J., Klein, J., Brown, B., Ratliff, B., Ruch, F., & Lee, J. T. (2011). Effects of co-adminstration of phytase and NSPase on broiler performance and bone ash. *Int. J. Poult. Sci* **10**, 933-939.

Cowieson, A. J. (2010). Strategic selection of exogenous enzymes for corn/soy-based poultry diets. *The Journal of Poultry Science* **47**, 1-7. https://doi.org/10.2141/jpsa.009045

Cozannet, P., Kidd, M. T., Neto, R. M., & Geraert, P.-A. (2017). Next-generation non-starch polysaccharide-degrading, multi-carbohydrase complex rich in xylanase and arabinofuranosidase to enhance broiler feed digestibility. *Poultry Science* **96**, 2743-2750. https://doi.org/10.3382/ps/pex084

De Araujo, W., Albino, L. F. T., Rostagno, H. S., Hannas, M. I., Pessoa, G. B. S., Messias, R. K. G., Lelis, G. R., & Ribeiro Jr, V. (2014). Sunflower meal and enzyme supplementation of the diet of 21-to 42-d-old broilers. *Brazil. J. Poult. Sci.* **16**, 17-24. https://doi.org/10.1590/1516-635x160217-24

De Vries, S., Pustjens, A., Kabel, M., Kwakkel, R., & Gerrits, W. (2014a). Effects of processing technologies and pectolytic enzymes on degradability of nonstarch polysaccharides from rapeseed meal in broilers. *Poultry Science* **93**, 589-598. https://doi.org/10.3382/ps.2013-03476

De Vries, S., Pustjens, A. M., Kabel, M. A., Kwakkel, R. P., & Gerrits, W. J. J. (2014b). Effects of processing technologies and pectolytic enzymes on degradability of nonstarch polysaccharides from rapeseed meal in broilers. *Poult. Sci.* **93**, 589-598. https://doi.org/10.3382/ps.2013-03476

Delwiche, S. R., Pordesimo, L. O., Panthee, D. R., & Pantalone, V. R. (2007). Assessing glycinin (11S) and β-conglycinin (7S) fractions of soybean storage protein by near-infrared spectroscopy. *Journal of the American Oil Chemists' Society* **84**, 1107-1115. https://doi.org/10.1007/s11746-007-1144-3

Douglas, M. W., Parsons, C. M., & Hymowitz, T. (1999). Nutritional evaluation of lectin-free soybeans for poultry. *Poultry Science* **78**, 91-95. https://doi.org/10.1093/ps/78.1.91

Eldridge, A. C., Black, L. T., & Wolf, W. J. (1979). Carbohydrate composition of soybean flours, protein concentrates, and isolates. *Journal of Agricultural and Food Chemistry* **27**, 799-802. https://doi.org/10.1021/jf60224a056

Engberg, R., Hedemann, M., Steenfeldt, S., & Jensen, B. (2004). Influence of whole wheat and xylanase on broiler performance and microbial composition and activity in the digestive tract. *Poultry Science* **83**, 925-938. https://doi.org/10.1093/ps/83.6.925

Erdaw, M., Perez-Maldonado, R., Bhuiyan, M., & Iji, P. (2017). Partial replacement of commercial soybean meal with raw, full-fat soybean meal supplemented with varying levels of protease in diets of broiler chickens. *South African Journal of Animal Science* **47**, 61-71. https://doi.org/10.4314/sajas.v47i1.10

Erdaw, M. M., Wu, S., & Iji, P. A. (2017). Growth and physiological responses of broiler chickens to diets containing raw, full-fat soybean and supplemented with a high-impact microbial protease. *Asian-Australasian Journal of Animal Sciences* **30**, 1303. https://doi.org/10.5713%2Fajas.16.0714

Esmaeilipour, O., Shivazad, M., Moravej, H., Aminzadeh, S., Rezaian, M., & Van Krimpen, M. (2011). Effects of xylanase and citric acid on the performance, nutrient retention, and characteristics of gastrointestinal tract of broilers fed low-phosphorus wheat-based diets. *Poultry Science* **90**, 1975-1982. https://doi.org/10.3382/ps.2010-01264

Fasina, Y., Garlich, J., Classen, H., Ferket, P., Havenstein, G., Grimes, J., Qureshi, M., & Christensent, V. (2004). Response of turkey poults to soybean lectin levels typically encountered in commercial diets. 1. Effect on growth and nutrient digestibility. *Poultry Science* **83**, 1559-1571. https://doi.org/10.1093/ps/83.9.1559

Gao, F., Jiang, Y., Zhou, G., & Han, Z. (2007). The effects of xylanase supplementation on growth, digestion, circulating hormone and metabolite levels, immunity and gut microflora in cockerels fed on wheat-based diets. *British poultry science* **48**, 480-488. https://doi.org/10.1080/00071660701477320

Graham, K., Kerley, M., Firman, J., & Allee, G. (2002). The effect of enzyme treatment of soybean meal on oligosaccharide disappearance and chick growth performance. *Poultry Science* **81**, 1014-1019. https://doi.org/10.1093/ps/81.7.1014

Haroon, M. (2006). Effect of supplementing different levels of Rovabio™ Excel (Liquid) in high fiber ration on broiler performance. M.Sc. thesis. Inst. Anim. Nutr. Feed Technol. Univ. Agri. Faisalabad.

Heger, J., Wiltafsky, M., & Zelenka, J. (2016). Impact of different processing of full-fat soybeans on broiler performance. *Czech J. Anim. Sci* **61**, 57-66. https://doi: 10.17221/8728-CJAS

Hollung, K., Øverland, M., Miladinovic, J., Martens, H., Narum, B., & Sahlstrøm, S. (2006). Evaluation of non-starch polysaccharides and oligosaccharide content of different soybean varieties (Glycine max) by near infrared spectroscopy. *NIR news* **17**, 18-20. https://doi.org/10.1255/nirn.910

Horvatovic, M., Glamocic, D., Zikic, D., & Hadnadjev, T. (2015). Performance and some intestinal functions of broilers fed diets with different inclusion levels of sunflower meal and supplemented or not with enzymes. *Brazilian Journal of Poultry Science* **17**, 25-30. https://doi.org/10.1590/1516-635x170125-30

Hosseindoust, A., Lee, S., Gook Nho, W., Song, Y. H., Shin, J. S., Laxman Ingale, S., Rathi, P. C., Choi, J., Chae, B., & Kim, J. (2019). A dose–response study to evaluate the effects of pH-stable β-mannanase derived from Trichoderma citrinoviride on growth performance, nutrient retention, and intestine morphology in broiler chickens. *Italian Journal of Animal Science* **18**, 147-154. https://doi.org/10.1080/1828051X.2018.1500872

Hymowitz, T., Collins, F., Panczner, J., & Walker, W. (1972). Relationship between the content of oil, protein, and sugar in soybean seed 1. *Agronomy Journal* **64**, 613-616. https://doi.org/10.2134/agronj1972.00021962006400050019x

Irish, G., & Balnave, D. (1993). Non-starch polysaccharides and broiler performance on diets containing soyabean meal as the sole protein concentrate. *Australian journal of agricultural research* **44**, 1483-1499. https://doi.org/10.1071/AR9931483

Irish, G. G., Maenz, D. D., & Classen, H. L. (1999). A new assay for functional lectins: the brush border lectin agglutination assay (BBLAA). *Animal feed science and technology* **76**, 321-333. https://doi.org/10.1016/S0377-8401(98)00214-4

MacIsaac, J., Burgoyne, K., Anderson, D., & Rathgeber, B. (2005). Roasted full-fat soybeans in starter, grower, and finisher diets for female broiler turkeys. *Journal of applied poultry research* **14**, 116-121. https://doi.org/10.1093/japr/14.1.116

Min, Y. N., Liu, F. Z., Hancock, A., Coto, C., Lu, C., Karimi, A., Yan, F., & Waldroup, P. W. (2011). Evaluation of Rovabio Max™ in normal and reduced-nutrient corn-soybean meal and distillers dried grains with solubles diets for broilers. *Int. J. Poult. Sci.* **10**, 786-795. http://www.pjbs.org/ijps/ab2077.htm

Mohammadigheisar, M., Kim, H. S., & Kim, I. H. (2018). Effect of inclusion of lysolecithin or multi-enzyme in low energy diet of broiler chickens. *Journal of Applied Animal Research* **46**, 1198-1201. https://doi.org/10.1080/09712119.2018.1484358

Munyaka, P., Nandha, N., Kiarie, E., Nyachoti, C., & Khafipour, E. (2016). Impact of combined β-glucanase and xylanase enzymes on growth performance, nutrients utilization and gut microbiota in broiler chickens fed corn or wheat-based diets. *Poultry Science* **95**, 528-540. https://doi.org/10.3382/ps/pev333

Mushtaq, T., Sarwar, M., Ahmad, G., Mirza, M., Nawaz, H., Mushtaq, M. H., & Noreen, U. (2007). Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass, and immunity responses of broiler chickens. *Poultry Science* **86**, 2144-2151. https://doi.org/10.1093/ps/86.10.2144v

Nadeem, M., Anjum, M., Khan, A., & Azim, A. (2005). Effect of dietary supplementation of non-starch polysaccharide degrading enzymes on growth performance of broiler chicks. *Pakistan Veterinary Journal* **25**, 183.

Neto, R. M., Ceccantini, M. L., & Fernandes, J. I. (2012). Productive performance, intestinal morphology and carcass yield of broilers fed conventional and alternative diets containing commercial enzymatic complex. *Int. J. Poult. Sci.* **11**, 505-516. http://www.pjbs.org/ijps/fin2115.pdf

Rahmatnejad, E., Pour, M. B., Mamuel, M., Mirzadeh, K., & Perai, A. H. (2011). The effects of dried tomato pomace and a multipleenzyme mixture supplementation (Rovabio Excel TM) on performance and carcass quality of broiler chickens. *Afr. J. Biotechnol.* **10**, 9207-9212. https://doi.org/10.5897/AJB10.2325

Ravn, J., Glitsø, V., Pettersson, D., Ducatelle, R., Van Immerseel, F., & Pedersen, N. (2018). Combined endo-β-1, 4-xylanase and α-l-arabinofuranosidase increases butyrate concentration during broiler cecal fermentation of maize glucurono-arabinoxylan. *Animal feed science and technology* **236**, 159-169.

https://doi.org/10.1016/j.anifeedsci.2017.12.012
Steenfeldt, S., & Pettersson, D. (2001). Improvements in nutrient digestibility and performance of broiler chickens fed a wheat-and-rye based diet supplemented with enzymes. *Journal of Animal and Feed Sciences* **10**, 143-158. https://doi.org/10.22358/jafs/67952/2001
West, M. L., Corzo, A., Dozier, W. A., Blair, M. E., & Kidd, M. T. (2007). Assessment of dietary Rovabio Excel in practical United States broiler diets. *J. Appl. Poult. Res.* **16**, 313-321. https://doi.org/10.1093/japr/16.3.313
Zdunczyk, Z., Jankowski, J., Juskiewicz, J., & Slominski, B. (2011). Dietary content and gastrointestinal function of soybean oligosaccharides in monogastric animals. In *Soybean-Biochemistry, Chemistry and Physiology*. IntechOpen. https://doi.org/10.5772/14856
Zou, J., Zheng, P., Zhang, K., Ding, X., & Bai, S. (2013). Effects of exogenous enzymes and dietary energy on performance and digestive physiology of broilers. *J. Anim. Sci. Biotechnol.* **4**, 1-9. https://doi.org/10.1186/2049-1891-4-14

Appendix

Composition of Octazyme®

Enzyme	**Units**	**Octazyme dry**
Xylanase	BXU[1]/gram	16000
β-glucanase	BXU/gram	2000
Cellulase	IU[2]/gram	320
Pectinase	IU/gram	210
α-Amylase	IU/gram	1000
Protease	IU/gram	150
β-Mannanase	IU/gram	100
α -Galactosidase	GALU[3]/gram	8

Composition provided by DMG Pakistan

Dosage 500g/ton feed

BXU[1]- birch xylan unit

IU[2]- international unit

GALU[3]- α-galactosidase unit