Spirulina as a livestock supplement and animal feed

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RUNNING HEAD: *Spirulina* supplementation in livestock

Summary

Spirulina (*Athrospira sp*.) is an edible microalga and a highly nutritious potential feed resource for many agriculturally important animal species. Research findings have associated *Spirulina* to improvements in animal growth, fertility, aesthetic and nutritional product quality. *Spirulina* intake has also been linked to an improvement in animal health and welfare. Its influence over animal development stems from its nutritive and protein-rich composition, thus leading to an increased commercial production to meet consumer demand. Consequently, *Spirulina* is emerging as a cost-effective means of improving animal productivity for a sustainable and viable food security future. However, our present knowledge of animal response to dietary *Spirulina* supplementation is relatively scanty and largely unknown. Therefore, the primary objective of this paper was to review past and current findings on the utilisation of *Spirulina* as a feed supplement and its impact on animal productivity and health. Only animals deemed to be of agricultural significance were investigated, hence only ruminants, poultry, swine and rabbits and their responses to dietary *Spirulina* supplementation are covered.

Keywords

Spirulina, pigs, sheep, milk, poultry, meat quality, growth

Introduction

Demand for animal products is increasing due to global changes in consumer tastes and expanding markets, particularly in developing countries where affluence is spreading (Myers and Kent 2003; Hopkins et al. 2007). However, two key obstacles must be overcome before this projected demand can be met; 1) increased competition for land, with urban sprawl, biofuel production and other agricultural applications taking up land otherwise used for animal production (Godfray et al. 2010; Poppi and McLennan 2010; Smith et al. 2010); and 2) climate change negatively affecting water and animal feed availability in current production regions (Gaunt et al. 2010; Poppi and McLennan 2010).

The identification of new feed resources is therefore crucial for sustainable animal production and future viability. Ideally, the new feed resource should have high nutritive value and conversion efficiency, be able to optimise animal product quality and use land and water efficiently (Poppi and McLennan 2010). Consequently, *Spirulina* is emerging as a potential candidate to meet these criteria. Feeding trials with *Spirulina* have been conducted in chickens, pigs, ruminants and rabbits. The main objective of this paper was to review the nutrient composition of *Spirulina*, integrate research findings from the feeding trials and highlight the effect of dietary *Spirulina* supplementation on animal health and productivity.

Historical background of Spirulina

Spirulina (*Arthrospira* sp.) is an edible, filamentous, spiral shaped cyanobacterium, formally classified as a blue-green microalga (Becker 2007; Gouveia et al. 2008; Gupta et al. 2008). It is naturally found in the alkaline lakes of Mexico and Africa (Belay et al. 1996; Shimamatsu 2004), where it has a long history as a food source for their ancient human inhabitants. *Spirulina* was 'rediscovered' relatively recently by

Leonard and Compere in the 1960s (Shimamatsu 2004), and has since become a mass produced product (Shimamatsu 2004; Spolaore et al. 2006). Presently, *Spirulina* is commercially produced world-wide (Table 1), and is used as a nutritional supplement for both humans and animals (Muhling et al. 2005), with approximately half of the total *Spirulina* production being used in livestock and fish feeds.

Spirulina is produced commercially within a nutrient-rich, liquid medium (Shimamatsu 2004), hence it can be produced with high land-use efficiency. For instance, *Spirulina* out yields many other traditional animal feed-types, including wheat, corn, barley and soybeans, in protein output per land unit (Dismukes et al. 2008; Kulpys et al. 2009). Furthermore, *Spirulina* can be actively produced using desalinated waste water (Volkmann et al. 2008) and animal faecal wastes to enrich the growth medium. This has been reported in pig (Chaiklahan et al. 2010) and cattle (Mitchell and Richmond 1988) faecal wastes with clearly consistent results demonstrating that *Spirulina* is safe to be fed back to livestock. These processes are described in detail by Hasdai et al. (1981) and Chaiklahan et al. (2010). Nonetheless, this highlights *Spirulina*'s capacity to cost-effectively treat wastes and recycle otherwise lost nutrients (Saxena et al. 1983).

Currently, *Spirulina* is relatively expensive to produce and purchase compared to other animal feeds. This makes its use impractical in many large-scale animal production operations. Additionally, *Spirulina*'s palatability, dried powdery form, and smell all limit its use in animal production (Becker 2007). However, *Spirulina*'s production cost can be lowered with developments in low-cost growth media and an improvement in the operational management of *Spirulina*'s nutrient use efficiency and growth rate (Shimamatsu 2004; Raoof et al. 2006; Peiretti and Meineri 2011). Furthermore, research into *Spirulina* delivery methods and its impact on product quality is increasingly allowing us a greater understanding of the practicalities of its use.

Nutritional value of Spirulina

Spirulina is nutrient-rich (Table 2). It contains all essential amino acids, vitamins and minerals. It also is a rich source of carotenoids and fatty acids, especially γ-linolenic acid (GLA) which infers health benefits (Howe et al. 2006). However, *Spirulina*'s high protein content distinguishes it as a new animal feed (Belay et al. 1993; Doreau et al. 2010).

Spirulina's nutritional value has been the topic of several reviews (Ciferri 1983; Belay et al. 1993; Diraman et al. 2009). Yet, its nutritional values are known to slightly vary depending on the production system. These differences have also been the topic of several studies (Vonshak and Richmond 1988; Tokusoglu and Unal 2003; Babadzhanov et al. 2004; Muhling et al. 2005; Mata et al. 2010).

Chickens

Chickens have been almost the exclusive focus of research into *Spirulina*'s usefulness in monogastric feed rations (Table 3). Ross and Dominy (1990) found that chicken growth rates declined when *Spirulina* replaced dehulled soybean meal in rations at either 10% or 20% of dry matter. Other studies that replaced groundnut cake (Saxena et al. 1983) or fishmeal (Venkataraman et al. 1994) with *Spirulina* in chicken diets found no variation in growth. Therefore, from these studies, it is apparent that the impact of dietary inclusion of *Spirulina* on chicken growth and growth rates depends on the feed-type it replaces in the ration. Although, it has been shown that dietary *Spirulina* levels of 50-100 g/kg of feed ration will maintain typical growth rates, levels exceeding 200 g/kg will bring about declined growth rates (Toyomizu et al. 2001).

Dietary *Spirulina* has been associated with greater cost efficiency in chicken production. Venkataraman *et al.* (1994) found that vitamin-mineral premixes normally added to chicken feed rations can be omitted when *Spirulina* is included, due to its nutrient-rich composition. Furthermore, chickens receiving dietary *Spirulina* have been found to be of better health than their unsupplemented counterparts (Venkataraman et al. 1994). This is due to increased functionality of macrophage and overall mononuclear phagocyte system indicative of enhanced disease resistance with increased dietary *Spirulina* levels in chickens (Qureshi et al. 1996; Al-Batshan et al. 2001). Qureshi et al. (1996) found improved chicken health with low dietary *Spirulina* levels of 10 g/kg in the ration, indicating greater production cost efficiency.

Spirulina has been shown to be an effective means of altering chicken product quality to meet consumer preferences. For instance, the total cholesterol content of eggs can be lowered by including *Spirulina* into layer hen rations (Sujatha and Narahari 2011). This is mainly due to *Spirulina*'s high antioxidant and omega-3 polyunsaturated fatty acids (PUFA) content that enriches the nutritional value of eggs at the expense of cholesterol content (Rajesha et al. 2011; Sujatha and Narahari 2011). Egg yolk colour has also been found to intensify linearly with increased dietary *Spirulina* levels (Ross and Dominy 1990; Sujatha and Narahari 2011). In white Leghorn layer hens, dietary *Spirulina* levels of 3-9% of the total ration was found to result in egg yolk colours best representative of consumer preferences (Saxena et al. 1983). Similar findings have been found in trials with Japanese quails (Ross et al. 1994). *Spirulina*'s effect on yolk colour results from its high level content of zeaxanthin, xanthophylls and other carotenoid pigments, particularly β-carotene, which accumulate within the yolk (Anderson et al. 1991; Takashi 2003). These same compounds have been found to also accumulate within the muscle tissue of chickens. Both Toyomizu et al. (2001) and Venkataraman et al. (1994) have reported this outcome with muscle tissue increasing in yellowness and redness with increasing levels of dietary *Spirulina*. Dietary *Spirulina* levels at 1% of the total ration in the week prior to slaughter has been found to result in broiler muscle tissue pigmentation at levels best representing consumer preferences (Dismukes et al. 2008).

Pigs

Research into pig growth responses to dietary *Spirulina* supplementation is inconsistent as depicted in Table 4. Hugh et al. (1985) found that crossbred weanling pigs receiving dietary *Spirulina* supplementation had growth rates of up to 9% higher than their unsupplemented peers. However, Grinstead et al. (1998), found no growth difference between *Spirulina* supplemented and unsupplemented pigs. This contrasting finding is attributable to differences in experimental procedures.

Different pig genotypes were used by Hugh et al. (1985) and Grinstead et al. (1998). The influence of heterosis in the crossbreds potentially affected the observed growth (Gillespie and Flanders 2010). Another explanation was that dietary protein digestibility decreased with increasing levels of *Spirulina* in pigs (Fevrier and Seve 1975) partly due to *Spirulina*'s complex cell wall structure being able to withstand the pig's digestive enzymes. Furthermore, differences in the basal diets of the pigs would affect any growth response, as much as the form in which the dietary *Spirulina* was provided. For instance, a difference in growth was shown between pigs fed pelletised and non-pelletised *Spirulina* (Grinstead et al. 1998; Grinstead et al. 2000). Pig health has also been suggested as a causal factor of the different outcomes in growth trials with *Spirulina* (Grinstead et al. 1998; Grinstead et al. 2000). Also, *Spirulina*'s usefulness in pig feeds will depend on the feed-type it is replacing. For instance, *Spirulina* has been demonstrated to be a viable replacement for dried skim milk powder in pig feed rations (Grinstead et al. 1998).

Pig rations containing *Spirulina* have been linked to improved boar fertility. Granaci (2007a) found that boars receiving a *Spirulina* extract had greater overall sperm quality than their unsupplemented counterparts in terms of increased sperm volume by 11% and motility and post-storage viability by 5%.

Ruminants

The ability of ruminants to digest unprocessed algal material (Gouveia et al. 2008) makes them especially suited to dietary *Spirulina* utilisation. This is further complemented by an efficient digestion of *Spirulina*'s carbohydrate fraction by ruminants when used in levels up to 20% of total feed intake, compared to other algal feed-types like *Chlorella* or *Scenedesmus obliquus* (Gouveia et al. 2008). *Spirulina* has been shown to increase microbial crude protein production and to reduce its retention time within the rumen (Quigley and Poppi 2009). Furthermore, approximately 20% of dietary *Spirulina* bypasses rumen degradation and is therefore available for direct absorption within the abomasum (Quigley and Poppi 2009; Panjaitan et al. 2010; Zhang et al. 2010).

When *Spirulina* is delivered to ruminants as a water suspension, it has been found to be preferentially consumed compared to pure water (Panjaitan et al. 2010). Moreover, *Spirulina*'s high sodium content increases water consumption and urine excretion (Panjaitan et al. 2010) in ruminants, although this is generally typical of algal feed-types (Marin et al. 2009).

Cattle

Spirulina trials using dairy cows have produced positive results with direct impact on productivity (Table 5). Kulpys et al. (2009) found that cows receiving dietary *Spirulina* had a 21% increase in their milk production. Furthermore, Simkus et al. (2007; 2008) showed an increase in milk fat (between 17.6% and 25.0%), milk protein (up by 9.7%) and lactose (up by 11.7%) in cows receiving *Spirulina* compared to those receiving no *Spirulina*. The saturated fatty acid content of milk decreased and mono- and poly-unsaturated fatty acids increased when cows received *Spirulina* (Christaki et al. 2012). These results could be attributable to *Spirulina*'s influence on microbial protein synthesis, avoidance of rumen degradation and its nutrient-rich composition. Moreover, these findings highlight *Spirulina*'s use in enhancing milk's health appeal.

Dietary *Spirulina* has also been associated with significant decreases in milk somatic cell count (Simkus et al. 2007), thus improving milk's food safety value. Additionally, dairy cows receiving *Spirulina* have been found to have improved body condition (8.5-11%) when compared to others receiving no *Spirulina* (Kulpys et al. 2009).

As with pigs, bull sperm quality has been shown to be improved with *Spirulina*. Sperm motility, concentration and post-storage viability were all positively affected when bulls received a bio-extract removed from *Spirulina* (Granaci 2007b). However, the effect of 'raw' dietary *Spirulina* on bull sperm quality needs to be further studied.

Sheep

Research into sheep production responses to dietary *Spirulina* is in its infancy (Table 5). Nonetheless, Bezerra et al. (2010) found that lambs receiving *Spirulina* have higher liveweights and average daily gains (ADG) than other lambs receiving no *Spirulina*. Findings from Holman et al. (2012) also show an increase in lamb liveweight with dietary *Spirulina* along with an increase in body condition and other body conformation traits. However, variation in ADG did not reach statistical significance. This divergence between the two studies was mainly due to age differences of the lambs and *Spirulina* suspensions in water used to deliver the *Spirulina*.

Shimkiene et al. (2010) has shown that pregnant ewes receiving *Spirulina* deliver heavier lambs (up 4.07%) with greater ADG compared to pregnant ewes receiving no *Spirulina*.

Rabbits

Spirulina has been trialled in the feed rations of commercially farmed meat rabbits (Table 6). Its inclusion in rabbit diets has been shown not to influence rabbit growth (Peiretti and Meineri 2008) or carcass yields (Peiretti and Meineri 2011). These findings may quell concerns that feed rations containing *Spirulina* would be less digestible than conventional rabbit diets. However, rabbits receiving dietary *Spirulina* have an increased total feed consumption compared to those receiving no *Spirulina* (Peiretti and Meineri 2008). Dietary *Spirulina* levels of 1% of total dry matter was found to improve crude protein digestibility in rabbits fed both low and high fat diets compared to those receiving no *Spirulina* (Peiretti and Meineri 2009). Hence, including *Spirulina* into rabbit diets may be useful when basal diets are high in fat to provide sufficient energy to ‘fuel’ optimal growth rates (Peiretti and Meineri 2009).

Rabbit meat quality has been shown to improve when rabbits received dietary *Spirulina*. For instance, Meineri et al. (2009) and Peirette and Meineri (2011) both identified dietary *Spirulina* as a causal factor for increasing γ-linolenic acid (GLA) and n-6/n-3 PUFA ratios within rabbit muscle lipid contents. This supports continued consumer preferable meat colour and appearance by improving rabbit meat's oxidative stability (Dalle Zotte and Szendro 2011). Furthermore, GLA has health benefits for humans (Howe et al. 2006), and its increased level in rabbit meat would appeal to health conscious consumers. Rabbit health has also been found to improve with dietary *Spirulina*, as rabbits receiving *Spirulina* had greater oxyhaemoglobin levels than those receiving no *Spirulina* (Meineri et al. 2009).

Conclusion

Spirulina is a promising new feed resource to support future animal production needs. Trials using dietary *Spirulina* in feed rations of many agriculturally significant animal species have already shown improvements in productivity, health, and product quality. However, many results contradict other findings, and together present an inconsistent trend of *Spirulina*'s usefulness as an animal feed. Therefore, further research with *Spirulina* in beef cattle, sheep, goats, llama, alpaca and deer, is needed to clarify its potential. Furthermore, investigations into *Spirulina*'s active ingredients and associated biological pathways would aid in broadening our knowledge, scope and applicable ramifications in sustainable animal production into the foreseeable future.

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Table 1. Some of the commercial producers of *Spirulina* and their global locations [1]

Name of Company	Location
Earthrise Farms	Calipatria, California (USA)
Cyanotech Corporation	Kailua Kona, Hawaii (USA)
Myanma Microalgae Biotechnology Project	Yangon, (Myanmar)
Hainan DIC Microalgae Co. Ltd.	Hainan (China)
Nao Pao Resins Chemical Co. Ltd.	Tainan, Taiwan (China)
Solarium Biotechnology	La Huayca (Chile)
Far East Biotechnology Co. Ltd.	Pig-Tung County, Taiwan (China)
DIC LIFETEC Co. Ltd.	(Japan)
Neotech Food Co. Ltd.	Banpong, Rajburi (Thailand)
Siam Algae Co. Ltd.	Bangsaothong (Thailand)
Ballarpur Industries Ltd.	Nanjangud, Mysore District (India)
TAAU Australia	Darwin, Northern Territory (Australia)
Sosa Texcoco	Lake Texcoco (Mexico)
Hills-Koor Algae Production	Elat (Israel)

[1] Adapted from Habib et al. (2008), Ciferri and Tiboni (1985), and Sanchez et al. (2003)

Table 2. A summary of *Spirulina*'s chemical and nutritional composition [1]

	Amount	**Unit**
Proximates		
Moisture	4 - 9	%DM
Fat (Mojonnier extraction)	4 - 16	%DM
Protein (N x 6.25)	60 - 70	%DM
Ash	3 - 11	%DM
Carbohydrates (total)	14-19	%DM
Energy	1504.0	kJ/100g
Crude Fibre	3 - 7	%DM
Lipid		
Minerals		
Calcium	1200	mg/kg
Magnesium	3300	mg/kg
Phosphate	13000	mg/kg
Potassium	26000	mg/kg
Sodium	22000	mg/kg
Fatty Acids		
Palmitic (16:0)	25.8 - 44.9	% of total fatty acids
Palmitoleic (16:1 omega-6)	2.3 - 3.8	% of total fatty acids
Stearic (18:0)	1.7 - 2.2	% of total fatty acids
Oleic (18:1 omega-6)	10.1 - 16.6	% of total fatty acids
Linoleic (18:2 omega-6)	11.1 - 12.0	% of total fatty acids
Gamma-linolenic (18:3 omega-6)	17.1 - 40.1	% of total fatty acids
Vitamins / Carotenoids		
β-carotene	140000	µg/100g
Total Carotenoids	1700	mg/kg
Provitamin A	2330000	IU kg^{-1}
Thiamin (B1)	34 - 50	mg/kg
B2	30 - 46	mg/kg
Niacin (B3)	130 - 150	mg/kg
B6	5 - 8	mg/kg
B12	1.5 - 2.0	mg/kg
Foliate	0.50	mg/kg
Amino Acids		
Lysine	2.60 - 4.63	%DM
Phenylalanine	2.60 - 4.10	%DM
Tyrosine	2.60 - 3.42	%DM
Leucine	5.90 - 8.37	%DM
Methionine	1.30 - 2.75	%DM
Glutamic acid	7.04 - 7.30	%DM
Aspartic acid	5.20 - 6.00	%DM

1 Adapted from Habib et al. (2008), Buddhadasa and Adorno (2004), Sanchez et al. (2003), Pascaud (1993), Babadzhanov et al. (2004), King (2012)and Mata et al. (2010).

Table 3. Studies on the effects of *Spirulina* on growth and health of chickens

Parameter	**Summary of results**	**References(s)**
Growth	Growth rates declined in 3 week old chicks fed *Spirulina* levels of 10% and 20% of diet	(Ross and Dominy 1990)
	Body weights of chicks fed *Spirulina* levels of 11.1 and 16.6% of diet were not different from the control group, receiving groundnut cake	(Saxena et al. 1983)
	Broilers fed *Spirulina* levels of 140 and 170 g/kg of diet and vitamin and mineral premixes omitted had no difference in dressing percentage compared to those receiving fishmeal or groundnut cake	(Venkataraman et al. 1994)
	Broilers fed *Spirulina* levels of 0, 40, or 80 g/kg of diet for 16 days did not significantly differ in body weights	(Toyomizu et al. 2001)
	Broilers fed *Spirulina* levels of 40 g/kg of diet had greater muscle redness and yellowness than the control group	(Toyomizu et al. 2001)
	White Leghorn and broilers fed *Spirulina* levels of 0, 0.001, 0.1, 1 and 10 g/kg of diet had comparable body weights after 7 weeks	(Qureshi et al. 1996)
Health	Chicks fed *Spirulina* levels of 10 g/kg of diet had increased NK-cell activity compared to the control group, showing an enhanced disease resistance potential	(Qureshi et al. 1996)
	Chicken phagocytic activity had an incremental linear increase with increasing dietary *Spirulina* levels of 0.5, 1 and 2% of diet	(Al-Batshan et al. 2001)
Product quality	White Leghorn hens egg total cholesterol levels were reduced when diets contained 150 g flaxseeds + 200 mg vitamin E + 3 g *Spirulina* per kg diet	(Sujatha and Narahari 2011)
	White Leghorn layers, aged 32 weeks, fed 20% whole flaxseeds and 5% *Spirulina* (w/w) produced eggs with higher levels of linoleic acid with less cholesterol	(Rajesha et al. 2011)
	Egg yolk colour score was higher in layers fed flaxseed diets with 5% *Spirulina* (w/w) compared to those on a flaxseed diet (20% w/w)	(Rajesha et al. 2011)
	Optimal egg yolk pigmentation was obtained by feeding *Spirulina* levels of 1% of diet, when diet is otherwise free of xanthophylls	(Anderson et al. 1991)
	Egg yolk carotenoids pigment and omega-3 fatty acid levels increase when White Leghorn hens fed 150 g flaxseeds + 200 mg vitamin E + 3 g *Spirulina* per kg diet	(Sujatha and Narahari 2011)

Table 4. Studies on the effects of *Spirulina* on growth and health of pigs

Parameter	Summary of results	Reference(s)
Growth	Crossbred weanling pigs fed *Spirulina* levels of 1.5 and 3% of diet had higher growth rates to the control group	(Hugh et al. 1985)
	Weanling pigs fed *Spirulina* pelleted diets had decreased average daily gain (ADG) while those receiving *Spirulina* in meal diets had improved ADG	(Grinstead et al. 2000) (Grinstead et al. 1998)
	ADG in pigs fed *Spirulina* levels of 2% of diet was greater than the control group, during days 14-28 post-weaning	(Grinstead et al. 2000) (Grinstead et al. 1998)
	Pigs fed *Spirulina* levels of 14% of diet had similar growth as those fed skim milk powder	(Grinstead et al. 1998)
	Increasing *Spirulina* levels in pig diets (0.5, 1 and 2% diet) showed only a numerical increase in ADG	(Grinstead et al. 1998)
Fertility	Boars fed BioR (extracted from *Spirulina*) at 1.5 mL/day had increased ejaculate volume and spermatozoa mobility compared to a control group	(Granaci 2007a)

Table 5. Studies on the effects of *Spirulina* on growth and health of ruminants

Species	**Parameter**	**Summary of results**	**Reference(s)**
Cattle	*Growth*	Dairy cows fed 200 g *Spirulina* daily were 8.5-11% fatter than the control group, evaluated using body condition score	(Kulpys et al. 2009)
	Productivity	Dairy cows fed 200 g *Spirulina* daily produced more milk than the control group	(Kulpys et al. 2009)
		Cows fed *Spirulina* levels of 2g/day (w/w) produced more milk than the control group	(Simkus et al. 2007)
		Spirulina levels of 0.15% of diet resulted in decreased rumen degradability of dietary crude protein	(Zhang et al. 2010)
	Product Quality	Milk from cows fed *Spirulina* levels of 2g/day had greater average milk fat, protein, and lactose than controls	(Simkus et al. 2007) (Simkus et al. 2008)
		Milk saturated fatty acid levels decreased while mono- and polyunsaturated fatty acids increased when crossbred Holsteins were fed *Spirulina* at 40 g/day	(Christaki et al. 2012)
		Spirulina fed at 2g/day to dairy cows reduces the somatic cell counts	(Simkus et al. 2007)
Sheep	*Growth*	6 month old lambs fed *Spirulina* levels of 10% (w/w) had greater liveweights than those given 20% (w/w) and the control group	(Holman et al. 2012)
		Lambs body condition scores incrementally higher in lambs fed *Spirulina* levels of 10 and 20% (w/w) compared to controls	(Holman et al. 2012)
		Lambs fed cow milk enriched with 10 g/day *Spirulina* had higher liveweights and growth rates during 15-30 days old than the control group	(Bezerra et al. 2010)
		Pregnant ewes fed pellets containing 2g *Spirulina* ad libitum produced newborn lambs with higher weights and average daily gains than those from control treatment ewes	(Shimkiene et al. 2010)

Table 6. Studies on the effects of *Spirulina* on growth and health of rabbits

Parameter	**Summary of results**	**Reference(s)**
Growth	Final weight and weight gain did not differ between rabbits fed *Spirulina* levels of 0, 5, 10, or 15% of diet	(Peiretti and Meineri 2008) (Peiretti and Meineri 2011)
	Feed intake of rabbits fed *Spirulina* levels of 5 and 10% of diet was greater than the control and 15% groups	(Peiretti and Meineri 2011)
	Rabbits receiving *Spirulina* levels of 1% of diet had increased crude protein digestibility in both low and high fat diets	(Peiretti and Meineri 2009)
	Spirulina levels of 10% of diet resulted in high feed intake compared to control group	(Peiretti and Meineri 2008)
Health	New Zealand White rabbits fed a high fat diet and supplemented *Spirulina* levels of 10 g/kg of diet had reduced reactive oxygen species and oxidative stress	(Meineri et al. 2009)
Product Quality	Γ-linoleic acid content in the peri renal fat and meat tissue in rabbits increased with *Spirulina* levels of 5, 10 and 15% of diet	(Peiretti and Meineri 2011)