Vitamins and poultry product quality

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The negative publicity of poultry diseases and feed contamination has tarnished the consumers' perception of poultry related products. The spotlight is being put on the stakeholders of the food chain to quest for quality, safety and traceability of poultry food products.

Vitamins play an important role in every link in the food chain in that they ensure the well being of live poultry and the quality and safety of poultry food products up to the dining table.

Poultry food products are able to convert into functional foods through their ability to store vitamin E. Vitamin C improves livability of broilers during handling, transportation and holding prior to slaughter. Vitamin D_3 metabolite like 25-OH-D_3 improves bone health of broilers as such the incidence of bone breakage in live poultry and in processed poultry food products can be lowered. Both vitamin E and 25-OH-D_3 are able to reduce downgrading of broiler carcases and processing condemns. Vitamin E is very effective in enhancing quality of poultry meat products by improving their oxidative stability and delaying the development of rancid deterioration and discolouration of meat.

Poultry disease outbreaks and feed contamination incidences have lowered the consumer confidence of consuming poultry related products.

At this juncture, the emergence of the consumer as a public voice increasingly put tremendous pressure on the stakeholders along the 'food chain' to quest for quality, safety and traceability.

The food chain's stakeholders are required to mount a concerted effort to restore the confidence of consumers. In addition, because of changes in market demands, from the traditional whole carcase to further processed poultry products, the quality and safety standards for poultry meat have also changed.

This article will look at how vitamins become indispensable to the food chain by virtue of their contributions to quality and safety of poultry products.

Food chain

The food chain links everything from the primary production to final consumption, including selection and breeding of broilers, feed ingredient suppliers, feed manufacturers, farmers, slaughterhouse personnel, value-added processors, wholesalers, retailers and consumers (Fig. 1). At any stage, relevant information regarding food quality and safety must be passed on to the next stakeholder of the food chain.

Vitamins are indispensable to every link in the food chain in that they ensure the well being of live poultry and the quality and safety of poultry food products up to the dining table.

Vitamin nutrition

Vitamins must be present in sufficient quantities in poultry diets to ensure the animal efficiently utilises carbohydrates, proteins, fats, minerals and water for health, maintenance and production functions

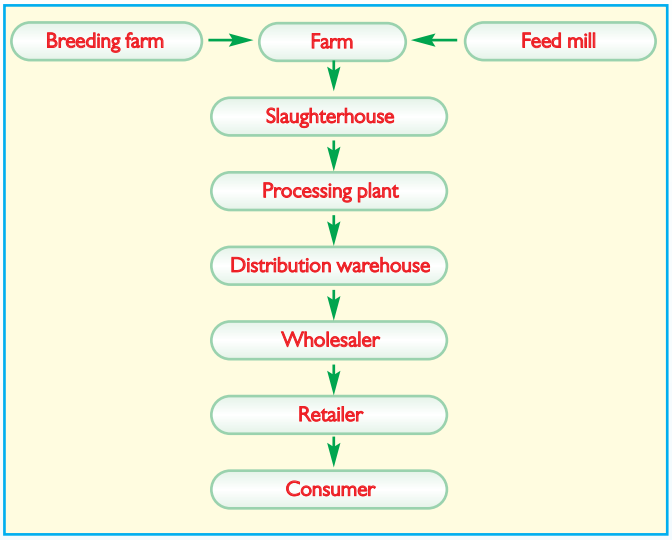

Fig. 1. The food chain.

(converting nutrients into muscle foods).

Modern birds have a high propensity for growth and protein accretion. Vitamins, in particular the B group vitamins, are very important because they are highly interactive in these metabolic processes.

The use of optimal levels of B group vitamins has been proven to be very beneficial in improving growth, carcase performance and mortality.

Also, modern birds are very susceptible to stresses, therefore, vitamins like C and E involved in alleviating stress and in antioxidant defence mechanisms are of particular importance.

It is important that all vitamins are considered and supplemented col-

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Table 1. DSM vitamin supplementation guidelines for domestic animals 2004 – Optimum Vitamin Nutrition for Poultry.

Poultry[1]	A	D_3[2]	E[3]	K	B_1	B_2	B_6	B_{12}[4]	Niacin	D-Panto-thenic acid	Folic acid	Biotin	C[5]	Choline	Hy•D[6] 25-OH-D_3
	IU	IU	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg	mg
Broilers starter, 1-21 days	8000–12500	3000–5000	150–240[7]	2–4	2.0–3.0	7–9	3.0–6.0	0.015–0.040	50–80	10–15	1.0–2.0	0.15–0.30	100–200	300–600	0.050
Chicks, growers/ replacement	7000–10000	1500–2500	20–30	1–3	1.0–2.5	4–7	2.5–5.0	0.015–0.025	25–40	9–11	0.8–1.2	0.10–0.15	100–150	200–400	0.050
Hens/ ducks, laying	8000–12000	2500–3500	15–30[8]	2–3	1.5–3.0	4–7	3.0–5.0	0.015–0.025	20–50	8–10	0.5–1.0	0.10–0.15	100–200	300–500	0.050
Broilers, 22 days-market	8000–12000	2000–4000	30–50[9]	2–4	2.0–3.0	5–8	4.0–6.0	0.020–0.030	40–80	10–15	1.0–2.0	0.15–0.30	100–200	300–500	0.050
Hens, breeding	10000–14000	2500–3000	50–100	2–4	2.0–3.0	8–12	4.0–6.0	0.020–0.040	30–60	12–15	1.5–2.5	0.20–0.40	150–200	300–500	0.050
Ducks/geese	12000–15000	3000–5000	40–80	3–5	2.0–3.0	7–9	5.0–7.0	0.020–0.040	50–70	10–15	1.0–2.0	0.10–0.15	100–200	300–500	0.050
Ostrich/emu	12000–16000	3000–4000	40–60	2–4	3.0–5.0	10–20	6.0–8.0	0.050–0.100	80–100	12–20	2.0–4.0	0.20–0.35	200–250	600–800	0.050

Vitamin premix type	Standard (Control)		Optimum (Experimental)	
Vitamin A (IU/kg diet)	8100		12000	
Vitamin D_3 (IU/kg diet)	2160		3500	
Vitamin E (mg/kg diet)	6.90		50	
Vitamin K_3 (mg/kg diet)	1.43		3.00	
Vitamin B_1 (mg/kg diet)	0.91		3.00	
Vitamin B_2 (mg/kg diet)	3.94		7.00	
Vitamin B_6 (mg/kg diet)	1.63		5.00	
Vitamin B_{12} (mg/kg diet)	12.30		25.00	
Niacin (mg/kg diet)	21.40		50.00	
Pantothenic acid (mg/kg diet)	7.45		10.00	
Folic acid (mg/kg diet)	0.31		1.00	
Biotin (mg/kg diet)	0.02		0.15	
Vitamin C (mg/kg diet)	0		100	
Ventilation	**Good**	**Poor***	**Good**	**Poor***
Whole egg vitamin A level (mcg/kg)	1771.5	1698.0	1844.1	1866.6
Whole egg vitamin E level (mg/kg)	13.38	12.50	40.00	46.12
Whole egg vitamin B_1 level (mg/kg)	0.52	0.52	0.58	0.72
Whole egg vitamin B_2 level (mg/kg)	4.05	3.85	4.08	4.15
Whole egg vitamin B_{12} level (mg/kg)	14.38	14.08	20.30	24.35
Whole egg pantothenic	15.60	14.30	18.38	18.62
Whole egg folic acid level (mg/kg)	0.51	0.41	0.71	0.64
Whole egg biotin level (mg/kg)	229.50	210.00	323.50	326.25

**Poor ventilation manipulated to increase air ammonia concentration by restricting the ventilation rate.*

Table 2. Effects of optimum vitamin levels and ventilation stress conditions on vitamin content of whole egg from 22-38 week old laying hens (Perez-Vendrell et al., 2002).

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lectively and guided by the concept of Optimum Vitamin Nutrition (OVN), whereby all known vitamins are supplemented in the diet at levels that allow animals to achieve optimum health and productivity and producers to realise improved economic return (Table 1).

The OVN facilitates continuous updates of vitamin supplementation levels to reflect progress in genetic, environmental and production factors. It offers a dynamic aspect to vitamin nutrition, taking account of changes in commercial production targets, improved genetics, nutritional and health status, stresses of physiological, immunological and environmental origins, vitamin instability and antagonists, feed contamination with mycotoxins and environmental conditions.

They also allow a margin of safety. Some vitamins are supplemented at supranutritional levels for their specific functions such as enhancing immunity and quality of poultry food products.

Table 3. Effects of optimum vitamin levels and high density stress conditions on growth performance and meat quality parameters of 0-40 day old broilers (Hernandez et al., 2002).

Vitamin premix type	Standard (Control)		Optimum (Experimental)	
Vitamin A (IU/kg diet)	13000		12500	
Vitamin D_3 (IU/kg diet)	2600		4000	
Vitamin E (mg/kg diet)	18.90		225.00	
Vitamin K_3 (mg/kg diet)	2.20		4.00	
Vitamin B_1 (mg/kg diet)	1.40		3.00	
Vitamin B_2 (mg/kg diet)	6.20		9.00	
Vitamin B_6 (mg/kg diet)	3.00		6.00	
Vitamin B_{12} (mg/kg diet)	21.20		40.00	
Niacin (mg/kg diet)	33.00		60.00	
Pantothenic acid (mg/kg diet)	10.40		15.00	
Folic acid (mg/kg diet)	0.68		2.00	
Biotin (mg/kg diet)	0.07		0.25	
Vitamin C (mg/kg diet)	0		100	
Pen density (birds/pen	**70**	**90**	**70**	**90**
Body weight (g)	2268	2059	2341	2122
Weight gain (g/day)	55.71	50.47	57.54	52.04
Feed intake (g/day)	96.63	91.66	100.71	92.73
Feed:gain(g/g)	1.746	1.818	1.746	1.801
Breast yield (% of liveweight)	16.33	15.61	16.59	15.84
Breast lipid peroxidation (nmol TBARS/g tissue)	0.51	0.34	0.28	0.25
Breast meat vitamin E level (mg/kg tissue)	1.78	2.48	11.15	14.25
Breast meat vitamin B_1 level (mg/kg tissue)	0.67	0.56	0.69	0.72
Breast meat pantothenic acid level (mg/kg tissue)	13.85	11.56	13.22	16.28

Bio-storage warehouse

When poultry products are converted into functional foods through their ability to store vital antioxidant vitamins like vitamin E, they are able to give a boost to human health by providing readily available nutrients to human metabolism. In addition, this is a win-win situation for the shelf life and, therefore, quality and safety of the products and the health of consumers.

Eggs from hens fed elevated vitamin levels have higher concentrations of vitamin A, E, B_1, B_2, B_{12}, folic acid and panthothenic acid and, therefore, higher nutritional values and lower susceptibility of egg lipids to lipid peroxidation (Table 2).

Similarly, breast meat from broilers fed elevated vitamin levels have higher concentrations of vitamins E and B_1 and panthothenic acid (Table 3).

Handling and transport.

Significant economic losses are borne by the grower as a result of bird mortality during handling and loss of body weight from catabolism and dehydration during transportation to and holding at the slaughterhouse.

Additional losses are experienced by the processor, including the loss of yield after slaughtering and processing. These losses are the cumulative result of several stresses. Provision of vitamin C in drinking water prior to catching, handling, transportation and holding before slaughter minimises stress induced broiler mortality and improves poultry processing yields (Tables 4 and 5).

Trial	Hot carcase yield (WOG)(%)		Chilled carcase yield (WOG)(%)	
	Control	Ascorbic acid	Control	Ascorbic acid
1	69.49	70.81	71.33	72.31
2	67.08	67.74	68.35	70.15
3	65.48	66.11	67.01	68.36
4	66.13	66.79	67.77	68.47
5	64.53	65.26	65.57	66.84
6	65.03	65.57	66.97	67.42
Average	66.33	67.05	67.83	68.93

**976mg ascorbic acid/kg administered via drinking water 24 hours prior to slaughter*

Table 4. Effects of ascorbic acid* on carcase yield of broilers (Krautmann et al., 1990).

Broiler farm	Control	Ascorbic acid
1	0.10	0.09
2	0.42	0.14
3	0.58	0.16
Average	0.36	0.13

**1000mg ascorbic acid/L administered via drinking water 24 hours prior to handling and transportation.*

Table 5. Effects of ascorbic acid* on broiler mortality (%) during transportation (Bains, 1999).

Bone health

Skeletal problems like field rickets and tibial dyschrondroplasia are commonly found in commercial broiler flocks. These problems are partially related to infections as well as factors affecting malabsorption of nutrients, in particular vitamin D.

Supplementation of a vitamin D_3 metabolite like 25-hydroxyvitamin D_3 has been shown to effectively correct skeletal problems associated with broilers (Table 6).

Numerous studies show that the intestinal uptake of 25-hydroxyvitamin D_3 occurs independent of bile acid secretion and micelle formation compared to vitamin D_3.

Furthermore, 25-OH-D_3 is absorbed more rapidly than vitamin D_3 (Table 7). This has tremendous

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Table 6. Effects of 25-OH-D3 on the incidence and severity of tibial dyschrondroplasia in 0-42 day old male broilers (Fritts & Waldroup, 2003).

25-OH-D_3 (mcg/kg diet)	TD incidence (%)	TD severity (%)
3.125	87.50	56.25
6.25	78.13	40.63
12.5	65.63	12.50
25	59.38	9.38
50	46.88	12.50
100	34.38	9.38

Intestinal length (cm)	Vitamin D_3	25-OH-D_3
20	57	38
40	64	87
60	64.5	86.5
80	65	80
100	64.5	84

Table 7. Cumulative intestinal absorption (% of intake) of vitamin D3 and 25-OH-D3 in broiler chickens (Bar et al., 1980).

Vitamin D_3 (IU/kg diet)	25-OH-D_3 (mcg/kg diet)	Plasma 25-OH-D_3 (nmol/L)	
		Control	MAS-infected
2200	0	100	18
3800	0	124	42
2200	37.5	186	171
3800	37.5	184	163

Table 8. Plasma 25-OH-D3 (nmol/L) in six day old broiler chickens infected with malabsorption syndrome (Gill, 2002).

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implications to birds with enteritis or malabsorption syndrome with which the nutrient transfer across the gut mucosa is negatively affected.

Under these conditions, the absorption of 25-OH-D_3 is superior to that of vitamin D_3 (Table 8).

The incidence of bone breakage during catching, loading, unloading and shackling and processing can be high if broilers have unhealthy bones. This not only affects the meat quality but also presents a product safety concern when bone fragments are unintentionally included in boneless meat.

Dietary vitamin E (mg/kg diet) (starter/grower/finsher)	Control (50/50/50)	Experimental (240/50/50)
	% of control	
Processing yield		
Total yield	100	103.4
Breast	100	102.6
Leg	100	102.9
Wing	100	112.2
Processed leg meat grade		
Grade I	100	112.3
Grade II	100	86.9
Processing condemns		
Plant total	100	51.9
Breast	100	65.8
Leg	100	49.2
Wing	100	46.2

Table 9. Effects of vitamin E on processing yield and condemnation in 0-47 day old commercial broilers (Bird and Boren, 1999).

Wholesomeness

Wholesomeness, one of the concerns of poultry meat quality, has increasingly received great attention because of its relationship to whole carcase and parts condemnation and downgrading. A broiler flock that can command high processing yields and less downgrades or condemns is likely to meet with less immunological challenges and be in better health. It has been demonstrated that supranutritional levels of vitamins can provide additional beneficial effects. Vitamin E is the most powerful lipophilic antioxidant known in nature and is a potent free radical scavenger. Free radicals are produced in the normal course of metabolism by respiration in mitochondria, by macrophages and heterophils during phagocytosis, in subcellular membranes and during the enzymatic production of eicosanoids (prostaglandins, prostacyclins and leukotrienes).

Frequently, free radical production is in excess of the amount necessary to respond optimally to a disease challenge. Under these circumstances, antioxidant defences are necessary to detoxify the free radicals and prevent them from destroying sensitive molecules within host cells. Vitamin E serves in the first line of this antioxidant defence, as it is preferentially deposited in the lipid-rich, easily oxidised cellular membranes. Vitamin E is unique in its ability to scavenge and quench free radicals in a lipid environment, minimising free radical induced damage and preserving the functional integrity of cellular membranes.

In doing so, supranutritional levels of vitamin E are effective in enhancing immunity, reflected in the improvement of growth performance, livability and processing yield and enhancing the wholesomeness of poultry products (Table 9).

25-hydroxy vitamin D_3 has been shown to reduce the incidence of whole bird, airsacculitis and cellulites condemns in the processing of broilers (Table 10).

Condemn category	Control	25-OH-D_3
	% of control	
Farm condemns	100	96.5
Whole bird condemns	100	83.7
Airsac condemns	100	60.0
IP condemns	100	33.3

Table 10. Effects of 25-OH-D3 on processing yield and condemnation in commercial broilers (APSI, 2004).

Vitamin E (mg/kg diet)	α-tocopherol (mcg/g)		TBARS (mg malonaldehydes/kg)	
	Raw burgers	Cooked burgers	Raw burgers	Cooked burgers
20	0.58	0.64	1.68	2.93
300	3.56	3.29	0.73	1.46
600	5.67	5.60	0.63	1.18

Table 11. Effects of vitamin E feeding for 21 weeks on α-tocopherol contents and TBARS of burgers made from turkey breast muscle (Wen et al., 1996).

Meat quality

Lipid peroxidation occurs during the conversion of muscle to meat. As a result, fresh poultry meat has a rather short shelf life. Lipid peroxidation is accelerated during subsequent handling, processing, cooking and storage of meat. Besides bacterial spoilage, lipid peroxidation is recognised as the major cause of deterioration of muscle foods.

Furthermore, lipid peroxidation releases various undesirable breakdown products, giving rise to typical off-odours and off-flavours of rancid meat and being considered to be harmful for human health.

Moreover, through oxidation of myoglobin, an unpleasant change of surface meat colour occurs. Vitamin E (α-tocopherol) is nature's most powerful lipid soluble antioxidant, being able to break the free radical induced chain reaction of lipid peroxidation. Numerous studies with meat from poultry, fed on diets supplemented with elevated levels of vitamin E have shown that the oxidative stability of both lipids and myoglobin was improved and that the development of rancid deterioration and discolouration of the meat was significantly delayed.

These effects were observed in fresh, cooked and processed meat under various conditions of refrigerated or frozen storage and resulted in a considerable extension of the shelf life of a variety of poultry products (Tables 11 and 12).

Furthermore, sensory properties such as flavour, tenderness and juiciness were positively influenced by high vitamin E supplementation of birds. When including elevated levels of polyunsaturated fatty acids in the diet of poultry in order to produce muscle foods with a more highly unsaturated profile, supranutritional dietary vitamin E was demonstrated to counteract the increased susceptibility of such meat to rancid deterioration.

Neither direct addition of vitamin E during processing nor the use of most alternative antioxidants showed a similar protective potential as dietary vitamin E.

It was, therefore, concluded that supplementation of poultry via the feed with extra vitamin E was the most promising approach to achieve and maintain an optimum quality of poultry meat.

Conclusion

Vitamins must be present in sufficient quantities in poultry diets to ensure the animal efficiently utilises carbohydrates, proteins, fats, minerals and water for health, maintenance and production functions (converting nutrients into muscle foods).

Some vitamins are supplemented at supranutritional levels for their specific functions such as enhancing immunity and quality of poultry food products. Vitamins are, therefore, indispensable to every link in the food chain, ensuring the well being of live poultry and the quality and safety of poultry food products up to the dining table. ■

Table 12. Effects of vitamin E on TBARS in thigh meat from broilers fed differing fat sources (Maraschiello et al., 1999).

Vitamin E (mg/kg diet)	Raw thigh meat			Cooked thigh meat		
	Lard	Sunflower oil	Olive oil	Lard	Sunflower oil	Olive oil
	TBARS (mcg/g muscle tissue)					
20	0.99	1.07	1.15	7.52	11.75	10.23
200	0.29	0.41	0.20	1.24	3.69	1.32