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Role of Carotenoids in Poultry Industry in China: A Review

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Abstract
The poultry as a rapidly growing global industry, occupies a very crucial position in the economy of China. Based on valid reason and available data, pigmentation plays a key role in attracting and convincing consumers demand on a yellow bird, because it is perceived as an indication of health. It was observed that broiler carcass skin and meat color affect the consumer's final judgment on the quality and values of poultry products in China, as well as in some other countries. Broiler chickens with a yellow skin color have been shown to be considered desirable by consumers while chickens with less desirable coloring have a lower market value, and are purchased less often by consumers. These compounds are not naturally synthesized by chickens, instead they are mostly derived from diet. However, for decades, carotenoid have attracted attention for promoting health, skin coloration, improve sexual behavior, vitamin A precursors and antioxidant. As such, carotenoids are commercially important in broiler, agriculture, food, health and the cosmetic industries. In China properly formulated feed and carotenoids are a significant part of a successful poultry industry. In this review therefore, an attempt has been made to establish the role of carotenoids. Their importance in the overall economy of the country has been highlighted. Also some constraints and illegal use of pigments in broiler diets have been discussed. However, a workable strategy for the promotion of the poultry has been outlined to strengthen the natural and approved carotenoids to improve the socioeconomic conditions of the rural and urban dweller of the country besides practical knowledge to the farmers and poultry producers.

Keywords: Role of carotenoid, pigments , poultry industry, China markets

1. Introduction

The poultry industries, along with the overall economy of China, have tremendous development and expansion during the past thirty years. Based on data from the China Agricultural yearbook 2010, total egg production in 2009 had reached 27.425 MMT, a distant number one in the world and has occupied that position for more than 25 years. In 1985, poultry meat consumed is only 8% of total meat production whereas in 2009 this percentage had increased to about 21% with a total poultry meat product of 15.949 MMT. Per capita consumption of broiler meat increased from 1.03 kg in 1984 to currently over 9kg, an impressive eight fold jump. FAO data indicated that China's output of duck meat was at 5.658 MMT and goose meat at 2.331 MMT, which represented 69% and 94 % of the world output, respectively. Meat types in broilers in China include two major categories fastest growing white feathered western type birds and those with diverse, color-feathered local breeds, a better known one is yellow feathers, yellow skin and yellow shank. Annual output of commercial broilers were estimated to be 3.84 billion birds in 2010, a 9.7% increase over the previous year. Production of these type of broilers are concentrated more in the northern China, such as Shandong, Liaoning, Henan, and Jiangsu Province. Most of these types of birds are processed and marketed through supermarkets, fast food chain, factories, schools, and restaurants.

The poultry farms in China have made a significant contribution towards the enhancement of food production strategies and measures. Thus in China, the consumption of food is important, not only because it is essential for life, but also for psychological satisfaction involving the actual food in term of meat containing carotenoids. Carotenoids are class of natural fat soluble pigments found mainly in plants, algae, and various microorganisms. More than 750 carotenoids have been identified in nature (Britton et al., 2004), and thus plays important role in the coloration of many plants, invertebrates, fishes, amphibians, reptiles, and birds (Goodwin, 1984). These interesting compounds, most of which reveal a yellow to red color, have attracted the attention of biologists at least since the early 1800s. Carotenoids originating from marigold (Tagetes erecta L) and red pepper (Capsicum annuum L) have been used by the poultry industry for coloring eggs yolk and the skin of the chicken (Tyczkowski and Hamilton, 1991; Kirkpinar and Erek, 1999 a; Nys, 2000; Blanch and Herna´ndez, 2000). The major carotenoid in marigold is lutein (3,3′-dihydroxy-β,ε-carotene), occurring to more than 95% as diester, with lutein dipalmitate,myristate palmitate, and palmitates tea rate being the major compounds in native extracts. Therefore, marigold and red pepper meals provide rich sources of lutein and capsanthin esters, respectively.

For optimal egg yolk coloration, most studies have focused on the profile of carotenoids present in the egg yolk after feeding carotenoid-enriched diets (e.g., Philip et al., 1976; Tyczkowski and Hamilton, 1986a, b; Schaeffer *et al*., 1988b; Hamilton et al., 1990; Lai *et al*., 1996); An excellent overview was given by Nys (2000), who believed that chickens absorb lutein very well, unlike β, ε-and β, β-carotene typical Provitamin A carotenoids have fairly low capability to color egg yolk (Neamtu et al., 1976; Hencken, 1992). Likewise, viola-xanthin and neoxanthin have been reported to have the only low potential to color the egg yolk and the skin (Kuzmicky et al., 1969). The question whether free or originally esterified carotenoids are absorbed more efficiently is sometimes a point of controversy as (Hencken, 1992) found that free lutein is absorbed with greater efficiency than lutein mono or diesters in young broilers. The hydrolysis rate of lutein esters was estimated to be only 40 to 60% consequently, preceding saponification of feed coloring carotenoid esters, which converts lutein esters to free lutein, improves the digestibility of carotenoids in chickens. Similarly, saponification improves absorption of zeaxanthin and capsanthin derived from red peppers (Hamilton et al., 1990).

In contrast, (Philip et al., 1976) reported that lutein esters are better utilized by laying hens than crystalline lutein. They assumed that the solubility of carotenoid esters in lipids is higher compared to that of free crystalline forms. (Lai et al., 1996) found that the results of color measurements of egg yolk from hens fed the same levels of free and esterified red pepper carotenoids are not significantly different. Basic work was done by (Tyczkowski and Hamilton 1986 a, b; 1987) on the formation and distribution of carotenoid esters in the blood, egg yolk, and different chicken tissues. After feeding free lutein or lutein diesters to chickens in different experiments, monoesters appeared in the serum and in the liver, whereas in the toe web, an integumentary storage site, diesters were the predominant form.This finding indicates that in the blood, lutein is transported mainly in its free form but is re-esterified by local enzymes when it enters depository sites (Osianu and Nicoara, 1984; Tyczkowski and Hamilton, 1987). (Schaeffer et al., 1988b) studied in detail the metabolism of lutein in laying hens.

2. Key Challenges Associates With Broiler Carcass Pigmentations In China Market

Pigmentation is one of the most important characteristics that determine the consumer acceptance and the perceived quality of broilers prior to buying or consumption in many countries (Castañeda et al., 2005; Ouart et al., 1988). The color of skin, meat and egg yolk of broiler chicken plays an important role in the different parts of the world based on consumer's demands (Fletcher, 1999). In some parts of China, pigments have been applied for nearly 40 years and their uses has been permitted worldwide. This therefore, implies that a broiler carcass with a yellow skin color highly desirable. The carcasses that don't have the desire color downgrades their market value and such products are being rejected by the consumers. The demand by consumers for color in poultry carcass remains strong in different regions of the world, thus consumers prefer yellow skinned broilers, because they believe that yellow and red yellow pigmentation is often associated with healthy and fresh chicken (Liufa et al., 1997). Pigments are some kind of additive that can enhance the color of broilers and aquaculture animal products .These compounds cannot be synthesized by poultry therefore need to mostly intake from their diets (Breithaupt, 2007; Marusich and Bauernfeind 1981; Pérez-Vendrell et al., 2001). The poultry skin color is provided by the different carotenoid pigments present in the diet of birds that are accumulated in the skin and subcutaneous fat. Poultry use carotenoid pigmentation. These substances are also involved in growth metabolism and fertility (Scheldt, 1998). Various carotenoids work as a predecessor for the synthesis of vitamin A (Suri and Speake.1988), some provide protection to the body, act as physiological antioxidants (Burton, 1989), and thus enhances the immune system (Bendich, 1989: Prabhala, et al, 1991; Blanch, 1999). The influence of the xanthophyll, canthaxanthin , for pigmentation of egg yolks and broilers have been demonstrated by several researchers (Hencken, 1992; Saylor, 1986). Canthaxanthin can significantly enhance the scale of pigmentation in broilers when used in diets containing yellow carotenoids (Marusich and Bauernfeind 1981). Most extensively used sources of yellow pigments is the flower petals of marigolds (Tagetes erecta), which consist of about 2,000 mg/kg of carotenoids (Tyczkowski and. Hamilton, 1984). On the other hand healthy birds ingest pigments from their basal diet, which are transported in the blood to the subcutaneous fat tissues and skin, where they are deposited. This process is impaired in birds afflicted with diseases, especially intestinal infections and parasitic infestations (Tyczkowski et al., 1991). The majority of consumers desire a golden and red bird because it implies that the bird is reasonably free from health problems (Sunde, 1992). Most of the natural carotenoids that are related to poultry pigmentation occur in free form, but the Lutein in Tagetes petals occurs mostly as diesters of palmitic and myristic acids (Hencken, 1992). Feed carotenoids are absorbed in their free form; thus esterified hydroxycarotenoids have to be saponified before they are absorbed. Feed carotenoids occur in natural complex in about 60 to 90% trans-form and 10 to 30% cis-form. When evaluated in vitro, the trans isomer demonstrate a more effective pigment than the cis isomer because of the red hue and better stability (Hencken, 1992). However, a few studies in eggs have revealed that the cis:trans profile in yolk is quite stable, independent of the cis:trans profile of feed carotenoids, which would imply that there is no benefit of using trans-carotenoids in vivo (Hencken, 1992). Digested carotenoids are absorbed in different parts of the intestine; whereas, the absorption of lutein takes place in the duodenum and jejunum canthaxanthin which is absorbed in the small intestine is transported into the liver (Yczkowski and Hamilton, 1986) Subsequent to absorption, the carotenoids have rapidly been accumulated in broiler tissues (subcutaneous adipose layer, breast and shank skin, and toe-web), principally as the esterified form. Carotenoids are required by the immune system, as a detoxifiers, (Blanch, 1999). Hence, it has become a common practice in the poultry industry to add carotenoids into the diets of broilers in order to produce the yellow color of skin that is demanded by the consumers. Poultry feeds, especially broiler feeds in China are primarily corn-soybean meal type with additional protein ingredient including cotton seed meal, rapeseed meal, and corn byproducts. China is the largest soybean importing country. Their import record shows that about 52 MMT of crops were imported in the year 2010/2011 and are predicted at least a 10% increase for the coming year. The typical, corn and soybean-based commercial poultry diets not supply the necessary amount and type of xanthophylls to produce the deep yellow and orange yellow skin color that is preferred by many countries. Therefore, the color of broiler skin often are provided by carotenoid pigments that added to the diets of broilers and are subsequently deposited in the skin as fat.

3. Influence Of Carotenoids

As reviewed, animals are generally unable to synthesize carotenoids thus requires a dietary intake of plant products to meet consumer demands. In most animals, dietary carotenoids are cleaved to provide precursors for vitamin A biosynthesis (of which a deficiency leads to blindness) and are valuable for many physiological functions and thus promote human health (e.g. antioxidant activity, immunostimulants, yolk nourishment to embryos, photo protection, visual tuning as well as limiting age related macular degeneration of the eye) (Johnson, 2002; Krinsky and Johnson, 2005). A deficiency in vitamin A is responsible for the child (and maternal) mortality and it is estimated that a 23–34% reduction in preschool mortality can be expected from vitamin A program reaching children in undernourished settings (The State of the World's Children, UNICEF, www.un.org/en/mdg/ summit 2010, accessed 19 August 2011). The nutritional industry synthetically manufactures five major carotenoids on an industrial scale (e.g. lycopene, carotene, canthaxanthin, zeaxanthin and astaxanthin) for use in a range of food products and cosmetics, such as vitamin supplements and health products and as feed additives for poultry, livestock, fish and crustaceans (reviewed by Del Campo et al., 2007; Jackson *et al*., 2008). One of the most commercially valuable pigments, astaxanthin, is primarily synthesized by marine microorganisms, such as the green alga *Haematococcus pluvialis* and accumulates in fish such as salmon, thus, coloring their flesh red. Astaxanthin has been identified as a potential therapeutic agent treatment for cardiovascular disease and prostatic cancer (Fassett and Coombes, 2011). Carotenoids are accumulated in light exposed tissues, such as skin and as such have gained increased value in the cosmetic industries as a suitable compound for photoprotection due to their scavenging action on reactive oxygen species (ROS) and anti-inflammatory properties (Stahl and Sies 2007). Photo-oxidative damage affects cellular lipids, proteins and DNA are involved in the pathobiochemistry of erythema formation, premature aging of the skin, development of photodermatoses and skin cancer. Evidence shows that carotene, lutein and perhaps even lycopene, can prevent UV-induced erythema formation and contribute to lifelong protection against exposure to harmful effects of sunlight (Stahl and Sies, 2007). Apocarotenoids are also highly valued as additives in the food industry. Spices such as bixin (annatto), red collared, di-carboxylic monomethyl ester apocarotenoid are traditionally derived from the plant Bixarellana (also known as achiote). Saffron comes from the threadlike reddish colored female reproductive organs of the Crocus sativa flower (petals are coloured light purple), which is considered one of the worlds most expensive spices and widely used as natural colourant. The color is due to the degradation of carotenoids (e.g. zeaxanthin to crocin and crocetin), whereas the flavour arises from the accumulation of carotenoid cleavage oxidation products from zeaxanthin (e.g. mainly safranal and the bitter glucoside, picrocrocin). Safranal (2,6,6-trimethylcyclohexa-1,3-dien-1-carboxaldehyde) is easily synthesized by de glucosylation of picrocrocin and composes 70% of total volatiles from crocin flowers (Leffingwell, *2002;* Bouvier et al., *2003a;* Schwab et al., 2008). There is a growing interest in the impact of saffron carotenoids on human health due to their high antioxidant capacity (Verma and Bordia, 1998). Other carotenoid derived volatiles, such as ion one's are predominant norisoprenoid volatiles in the mature stigma tissue that are also important components of aroma and taste produced during flower and fruit development (Goff and Klee, 2006).

In order to achieve the desired color and meet the consumer demands, poultry feed producers usually increase the contents of xanthophylls in the diet by adding the natural and synthetic colorants (Fig, 1, 2and 3). There are various natural and synthetic sources of pigments used in poultry feed. There are those that usually combine natural yellow carotenoid (apo-ester,lutein, zeaxanthin), those among the synthetic red one's (canthaxanthin citranaxanthin, capsanthin, or capsorubin) and orange-II (banned dye). In China, the use of pigments has gradually changed from natural colorants to synthetic ones especially on banned dye. Orange-II dye belongs to a class of organic compounds known as azo-dyes (Mollah et al., 2004). Dyes are important chemical compound that can be found in foodstuff, pharmaceutical, cosmetic, textiles and leather industries (Hildenbrand et al. , 1999). Besides that, it could give adverse effects and often creates the toxicity, mutagenicity and carcinogenicity (Tan et al., 1999). Azo dye orange-II is known as acid orange 7 or 1-(4′-

sulfophenylazo) -2-naphthol contains a sulfonic group as a substitute. Therefore it is called a sulfonated azo dyes. It has the largest class of dyes in color index and classified as acid dyes. Sulphonated azo dyes have been widely used as coloring agents in foodstuffs, paper, textiles and so on. However, some of these dyes pose a potential risk to human health and are even carcinogenic (Boeninger, 1980). Nowadays, China and many other countries are regulating the use of azo dyes in foodstuffs. The use of these dyes in foods is strongly prohibited because of the health concerns related to their intake.

4. Animal Behaviour, Reproduction And Survival

Animals accumulate carotenoids where they are critical in determining sexual behaviour, reproduction and avoiding predation as well as parasitism. Fish and birds accumulate dietary carotenoids, which boost their immune system and advertise health, often leading to preferential selection by the sexual partner (McGraw et al., 2006*b*; Baron et al., 2008). Animals typically place different priorities on fitness-enhancing activities (e. g. gametic investment in females, sexual attraction in males) and carotenoid allocation appears to track such investment patterns in the two sexes (McGraw and Toomey, 2010). For example, environmental and physiological factors influence colour expression in house finches and the type of dietary carotenoids is one determinant of their ability to become bright red rather than drab yellow (McGraw et al., 2006*a*). A particular primacy of higher levels of cryptoxanthin was assigned to the coloration in the male house finches that become red and more sexually attractive. It is possible that the red house finches adopted selective foraging strategies for the most cryptoxanthin rich foods rather than grains and fruits, which typically contain the more common dietary yellow xanthophylls and carotenes (McGraw et al., 2006 *a*).

Finally, Hill (2000) observed that birds fed with diets rich in lutein and zeaxanthin turn only yellow, but grow red feathers when fed cryptoxanthin rich foods (e.g. tangerine juice). Perhaps, it is the metabolic precursors of cryptoxanthin such as 3-hydroxyechinenone, which provides the red carotenoid pigmentation (Hill, 2000). Another intriguing example is the flamingo, whose feathers are coloured bright rosy pink from the carotenoid pigments (derivatives such as canthaxanthin, main pigment found in the secretions, as well as small quantities of cryptoxanthin are likely to contribute to pink colouration) in the algae and various invertebrates (e.g. crayfish) that make up the bulk of a flamingo's diet. Curiously, the crustaceans accumulate astaxanthin whose spectral properties become modified by the barrel protein, crustacyanin, resulting in blue pigmentation that shifts to red upon protein pigment denaturation during cooking (Fig. 1; American lobster) (Krawczyk and Britton, 2001). A dietary source of carotenoids by the flamingo was found in the oils of uropygial secretions, which deposits over the plumage and growing feathers more frequently during periods when in a group, contributing some colour and possibly indicating a cosmetic function for mate choice. The cosmetic nature of accumulating carotenoids by painting canthaxanthin rich secretions onto their feathers to create a visually more attractive breeding partner appeared to enhance the frequency of their courting behaviour during mating seasons (Amat et al., 2010).

Carotenoids also play important roles in animals to avoid predation and reduce parasitism. For example, aphids (e.g. *Acyrthosiphon pisum*) are the first known animal to have acquired the carotenoid biosynthetic machinery to produce carotenoids such as torulene and dehydro- , -carotene, which provide a reddish colouration to distinguished them from their green forms, which accumulate -carotene, -carotene and -carotene (Moran and Jarvik, 2010).

5. Overall Production And Consumption Of Meat

The total production of raw meat has been consistently rising in China at an annual average rate of 5.8% during the past 30 years. In 2009, China was the world's largest producer of meat with 78.21 Mt. which was 28% of the world's total production of this raw meat in China, the production of pork, poultry, beef and mutton were 49.88 Mt., 16.44 Mt., 6.43 Mt. and 3.87 Mt respectively. The out-put of pork and mutton far exceeded the production of poultry and beef (Table 1). As the production of raw meat increased, the proportion of the different meat species changed (Table 2). One of the significant changes was the drop of pork output from 79.08% of total meat in 1978 to 63.93% in 2009. However, pork still has a dominant position in the total meat structure but its share of total meat production is still declining. The ratio of beef, mutton and chicken increased from 2.52%, 2.89% and 13.80% in 1978 to 8.31%, 5.08% and 22.68% in 2009, respectively. It is noteworthy that the meat consumption pattern was different in urban and rural areas in China as a result of differences in income level, education, meat availability and tradition. In urban households, 57% of meat consumption was pork and 13% was beef and mutton while pork accounted for 71% and beef and mutton for 9% of rural households (Gong *et al.*, 2011). In 2009, the annual per capita consumption of meat in China was 57.3 kg including 36.7 kg of pork, 12.0 kg of poultry, 4.8 kg of beef and 3.0 kg of mutton. Currently, the developmental philosophy of fresh meat in China is "stable development of the swine industry, active development of the poultry industry and fast development of the cattle and sheep industry". The main purpose of this policy is to improve the balance of consumption and the demand structure of meat consumption in China.

6. Safety Issues

China's safety issues have included antibiotic residues, contamination during transportation, microbiology contamination, illegal use of feed additives and carotenoids in feed and medicine, addition of toxic ingredients and toxic residues from the environment (Wang, 2009; Yang, 2009; Zhang et al., 2011). The government has been working diligently to increase the safety and the security of meat and meat products. For example, the State Council started a national safety inspection and correction process for pork safety as a priority in August of 2007. This was led by the Ministry of Commerce along with the Ministry of Public Security, the Ministry of Agriculture, the General Administration of Industry and Commerce, and the General Administration of Quality Supervision, Inspection and Quarantine. As a result of the four-month inspection, 1304 slaughter plants were closed and 7596 unregistered slaughtering plants were shut down, due to safety concerns and the breach of regulations. Other government special actions, led by the Ministry of Commerce in 2006, were aimed at establishing a quality assured pork system to improve "product quality and food safety special rectificationaction". The General Administration of Quality Supervision, Inspection and Quarantine was initiated in 2007 to improve the company awareness of using food additives and ingredients, as well as "quality and safety improvement action for agricultural food products" by the Ministry of Agriculture to improve food quality and safety as well as monitor additive residues in 2007. However, neither of these special actions, led by the central government, was able to achieve food security in China In recent years, there have been two serious food safety out-breaks: one involving milk contaminated by melamine, and the second, fresh pork contaminated by Clenbuterol (Chen, 2009; Liang et al., 2009; Zhang et al., 2009). The Ministry of Agriculture in 1997 banned the use of clenbuterol in animal feeds in China, but it is still being used illegally in livestock feed today to accelerate lean muscle growth (Liu, 2004; Meng et al., 2009). The presence of Clenbuterol in foods can cause serious side effects including heart palpitations, muscle tremors, nervousness, dizziness, nausea, vomiting, fever, chills and even death (Jin & Jin, 2011). In May 2006, more than 100 employees of Shatian Yintong glass plant in Dongguan of Guangdong province consumed animal lungs contaminated with clenbuterol resulting in illnesses including vomiting, diarrhea and fever. In September 2006, 336 persons were hospitalized with dizziness, profuse sweating and hand numbness due to the consumption of pork and pig organs with high content of Clenbuterol (Hong, 2007). According to a report from the Chinese government, food related Clenbuterol poisoning has been responsible for 18 incidents between 1998 and 2007 with more than 1700 persons becoming ill and one person dying.

Though poultry production in China is large in overall scale, however, the industry itself is still very diverse, scattered and production efficiency far behind that of the developed countries. A major portion of poultry production is still from those small scale farmers who generally lack stringent biosecurity measures, quality housing, and management skills. Currently, just like others livestock production sectors, poultry industries are facing several major challenges. Among the most significant ones include disease outbreaks, high cost of feed, short of affordable labors, restricted land use and stricter environment regulations. In recent years, the government at various levels have put policies to encourage large scale and more efficient animal production system. In line with this, big companies, including specialized farmers have started to invest heavily in large scale automated and controlled standard production facilities for better management, bioseutrity and disease prevention. As the economy in China continue to improve and urbanization continues to grow.

7. Conclusion

In the recent years, China has become one of the fastest growing economies in the world. In the coming years, the economy of China is expected to keep growing in the range of 5–10% per annum. The subject of carotenoids and the factors affecting it are very broad. The above written paragraph have led us to the conclusion on the great potential of carotenoids to enhancing the poultry production in the country .Therefore, the frequent use of unauthorized synthetic pigments should be avoided in poultry diets and instead high quality antioxidant pigments should be used in poultry diets to enhance the scale of broiler skin pigmentation for consumers demand. Further research is required to accurately determine the effects of unauthorized synthetic pigments in broiler meat, skin, and feed through GC-MS, FAB-MS, and ESI-MS methods on a large scale.

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Table 1: Meat Prodcutin In China and the world in 2009
China Statistical Yearbook 2010

Production	China (Mt.)	World (Mt.)	Proportion%	Ranking In the world
Pork	4987.90	10.6060	47	1
Mutton	386.70	1304.80	29.60	1
Poultry	1643.80	9130.80	18	2
Beef	642.50	6514.60	9.90	3

Table 2:The production (Mt.) and proportion (%) of different fresh meat in China.
FAOSTAT; China Statistical Yearbook 2010.

	Pork		Beef	Mutton	Poultry meat	Chicken	Duck	Goose	Total
1978	8.77	(79.08)	0.28(2.52)	0.32 (2.89)	1.53(13.80)	1.08	0.27	0.17	11.09
1979	10.87	(81.42)	0.32(2.40)	0.38 (2.85)	1.59(11.91)	1.11	0.29	0.18	13.35
1980	12.13	(82.01)	0.34(2.30)	0.45 (3.04)	1.66(11.22)	1.17	0.30	0.19	14.79
1981	12.67	(82.06)	0.35(2.27)	0.48 (3.11)	1.73(11.20)	1.22	0.31	0.19	15.44
1982	13.53	(82.30)	0.36(2.19)	0.53 (3.22)	1.81(11.01)	1.28	0.32	0.20	16.44
1983	14.01	(82.03)	0.4(2.34)	0.55 (3.22)	1.9(11.12)	1.36	0.33	0.21	17.08
1984	15.37	(82.72)	0.45(2.42)	0.59 (3.18)	1.94(10.44)	1.39	0.33	0.21	18.58
1985	17.57	(83.91)	0.51(2.44)	0.59 (2.82)	2.02(9.65)	1.45	0.34	0.21	20.94
1986	19.03	(83.14)	0.63(2.75)	0.62 (2.71)	2.32(10.14)	1.66	0.41	0.25	22.89
1987	19.49	(81.01)	0.84(3.49)	0.72 (2.99)	2.69(11.18)	1.93	0.47	0.29	24.06
1988	21.29	(79.71)	1.00(3.74)	0.80 (3.00)	3.25(12.17)	2.35	0.51	0.40	26.71
1989	22.35	(79.45)	1.12(3.98)	0.96 (3.41)	3.37(11.98)	2.42	0.53	0.41	28.13
1990	24.02	(78.96)	1.30(4.27)	1.07 (3.52)	3.74(12.29)	2.66	0.60	0.47	30.42
1991	25.82	(77.37)	1.58(4.73)	1.18 (3.54)	4.48(13.43)	3.17	0.67	0.64	33.37
1992	27.65	(75.94)	1.85(5.08)	1.25 (3.43)	5.12(14.06)	3.59	0.79	0.74	36.41
1993	29.84	(73.59)	2.37(5.84)	1.37 (3.38)	6.41(15.81)	4.57	0.98	0.85	40.55
1994	32.61	(72.90)	2.81(6.28)	1.48 (3.31)	7.17(16.03)	5.15	1.08	0.93	44.73
1995	33.40	(69.22)	3.60(7.46)	1.75 (3.63)	8.67(17.97)	6.06	1.28	1.33	48.25
1996	31.58	(68.89)	3.56(7.77)	1.81 (3.82)	8.79(19.18)	6.14	1.29	1.37	45.84
1997	35.96	(68.26)	4.41(8.37)	2.13 (4.04)	10.22(19.40)	7.24	1.46	1.51	52.69
1998	38.84	(67.85)	4.80(8.39)	2.35 (4.11)	11.22(19.60)	7.95	1.60	1.66	57.24
1999	40.06	(67.34)	5.05(8.49)	2.51 (4.22)	11.70(19.67)	8.17	1.81	1.72	59.49
2000	39.66	(65.95)	5.13(8.53)	2.64 (4.39)	12.41(20.64)	8.85	1.80	1.75	60.14
2001	40.52	(66.36)	5.09(8.34)	2.72 (4.45)	12.43(20.35)	8.86	1.80	1.75	61.06
2002	41.23	(66.14)	5.22(8.37)	2.84 (4.56)	12.75(20.45)	9.05	1.85	1.80	62.34
2003	42.39	(65.79)	5.43(8.43)	3.09 (4.80)	13.22(20.52)	9.26	1.95	1.85	64.43
2004	43.41	(65.68)	5.60(8.47)	3.33 (5.04)	13.12(19.85)	9.30	1.96	1.80	66.09
2005	45.55	(65.64)	5.68(8.19)	3.50 (5.04)	14.36(20.69)	10.30	2.11	1.91	69.39
2006	46.51	(65.61)	5.77(8.14)	3.64 (5.13)	14.67(20.69)	10.42	2.18	1.98	70.89
2007	42.88	(62.45)	6.13(8.83)	3.83 (7.69)	15.52(20.83)	10.86	2.35	2.23	68.66
2008	46.21	(63.48)	6.13(8.42)	3.80 (5.22)	15.76(22.88)	11.02	2.51	2.23	72.79
2009	49.88	(63.93)	6.43(8.31)	3.87 (5.08)	16.44(22.68)	11.44	2.66	2.33	76.50

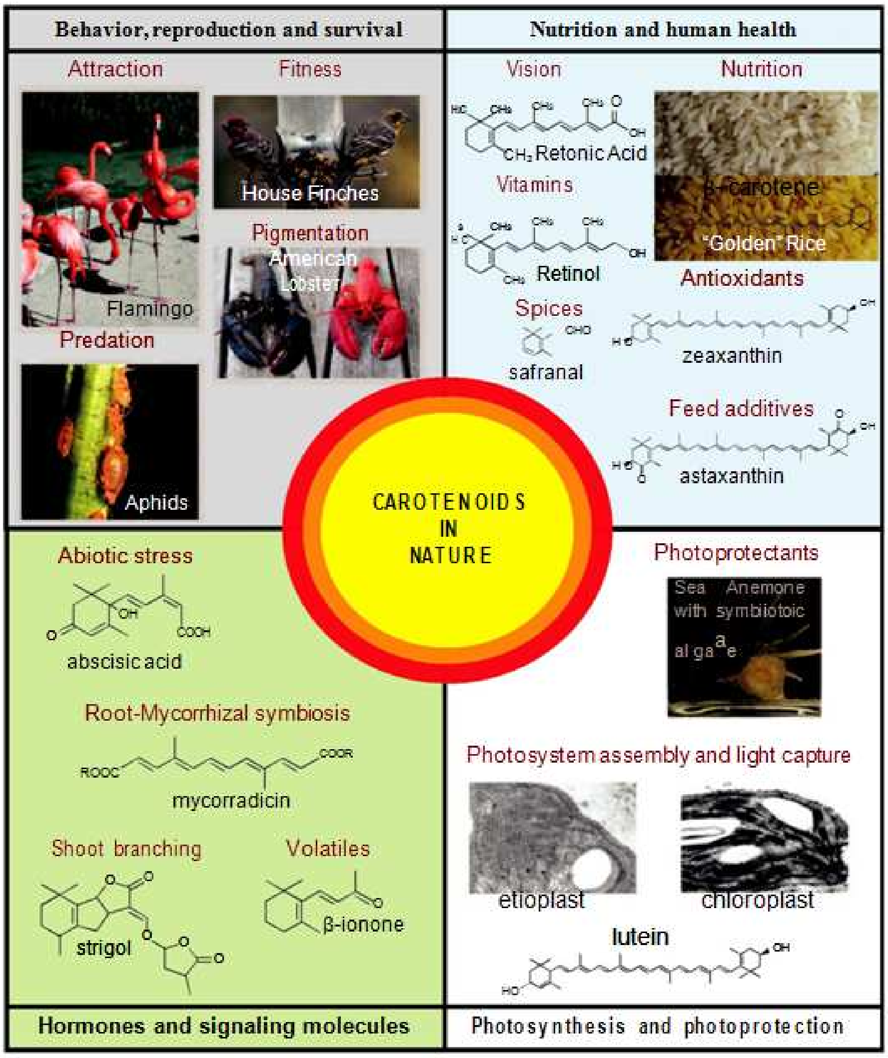

Fig. 1. The essential functions of carotenoids in animal and plant. Carotenoids play important roles in (1) promoting animal behaviour, reproduction and survival, (2) improving nutrition and human health, (3) assembly of photo systems, light capture and photo protection and (4) providing substrates for the biosynthesis of plant hormones and signalling molecules.

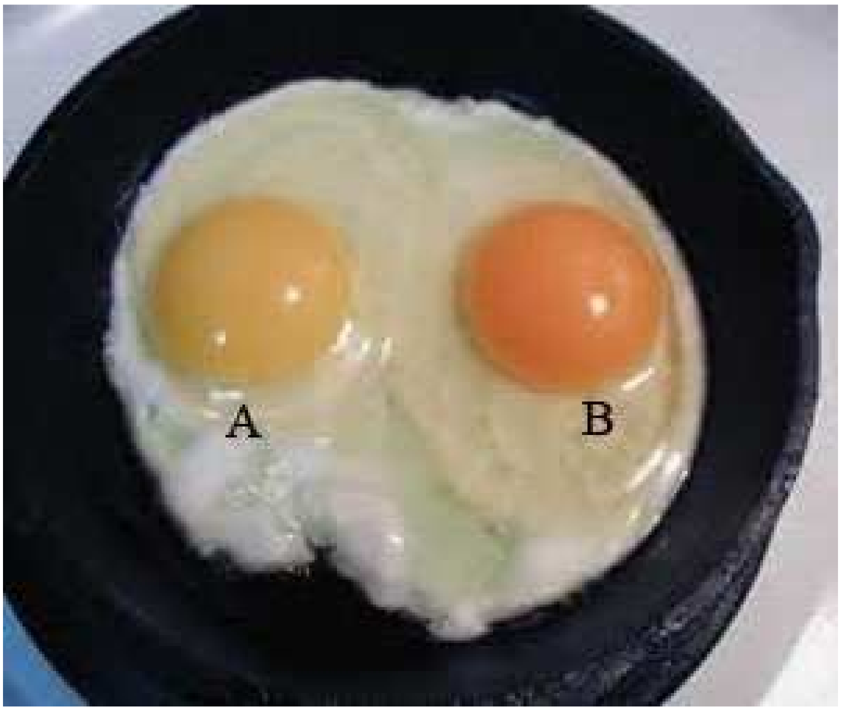

Fig. 2. The effect of dietary carotenoid on egg yolk. (A) Yolk contains natural carotenoid (B) Yolk contains synthetic carotenoid pigments

Fig. 3. Showing the effect of different dietary carotenoids on breast, vent, and shrank skin of broilers.

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