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Nutraceutical Aspect Of Canthaxanthin In Animal Feed Technology

Surojit Bera*

[1]Department of Microbiology, School of Bioengineering and Biosciences, Lovely Professional University, Punjab-144411, India

***Corresponding author:** Dr. Surojit Bera
E-mail: suromic@gmail.com

ABSTRACT
Synthetic food colorant and bioactive chemicals are now jeopardizing buyer's health safety due to their unwanted side effects. However, global demand for such chemicals are still in rising condition. Canthaxanthin is a naturally occurring keto-carotenoid which has a significant application in poultry industry, fishery science or aqua farming, cosmetics and nutraceuticals industries owing to its attractive colour and strong antioxidant property. Canthaxanthin also has certain involvements with antitumor activity and cancer, lipid metabolism, immune-modulatory activities etc. Animals generally acquire this pigment via their diet establishing the use of canthaxanthin as a feed supplement (especially poultry and fishery industry). In certain cases, other pigments and chemicals are used along with canthaxanthin to increase its stability and activity. Newly explored microbial sources for canthaxanthin from all over the globe, trying to retrieve its industrial hold over the chemical synthesis. Its production by unicellular microbes needs new comprehensive researches to ensure customers attention along with market demand from industrial sectors.

Keywords: Canthaxanthin; Antioxidant; feed supplement; Poultry

CANTHAXANTHIN (CX): A RED KETO-CAROTENOID

Canthaxanthin (CX) is a reddish-orange keto-carotenoid which belongs to xanthophyll cluster. CX is innately found in different bacteria, algae and some fungi. Variety of bird like flamingo, different carps and crustaceans become beautifully red colour due to the presence of CX. It is also widely used in feedstuff industry like poultries. The CX-mediated colour of foodstuff is now being considered as an imperative characteristic benchmark for customers. Figure1 shows a variety of natural objects where CX is present.

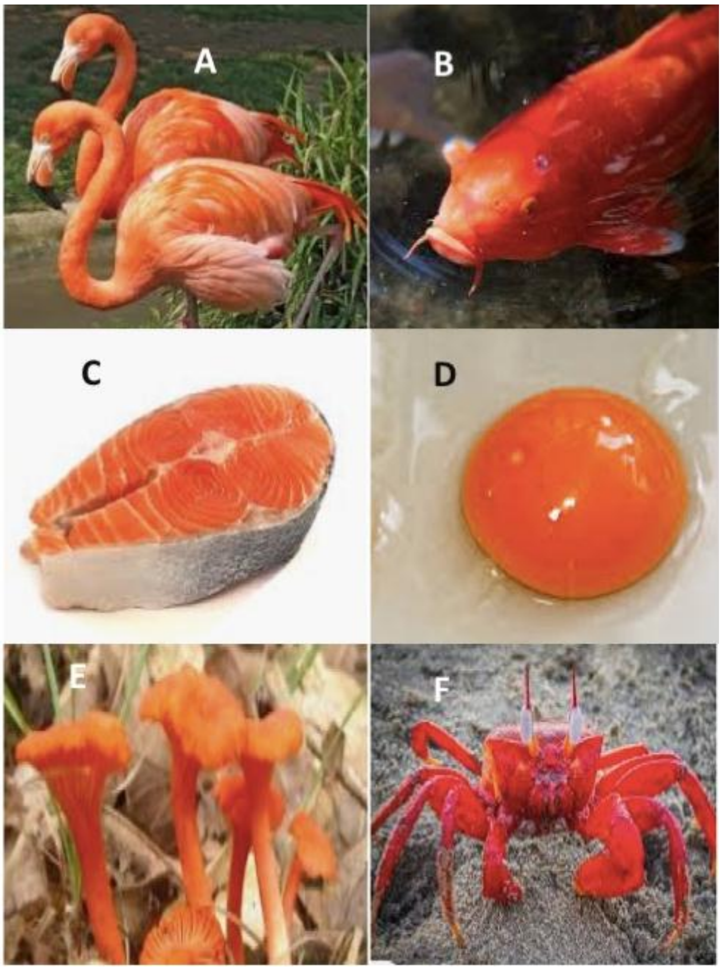

Figure 1. Incidence of CX: (A) 'flamingo' (*Phoenicopterus* sp.; Copyright: Erlebnis Zoo-Hannover), (B) 'koi carp' (*Cyprinus carpio* "Showa" or "Tancho Sanke"; Copyright: Koi-Zentrum-Todtenbier), (C) 'farmed salmon flesh' (*Salmo salar* L.; Norway), (D) 'egg yolks', (E) 'chanterelle edible fungus *Cantharellus cibarius*' and (F) 'crustaceans' [adapted and modified from Esatbeyoglu and Rimbach, 2016 (1)]

CX is one of the most important keto-carotenoid from the biotechnological perspective. The synthetic and bio produced counterpart constituted 33% of the whole US$455 million market as was projected to the year 2000. Besides, being an effective food colorant, CX has been attributed with nutraceutical importance. Figure 2 shows the molecular structure of CX

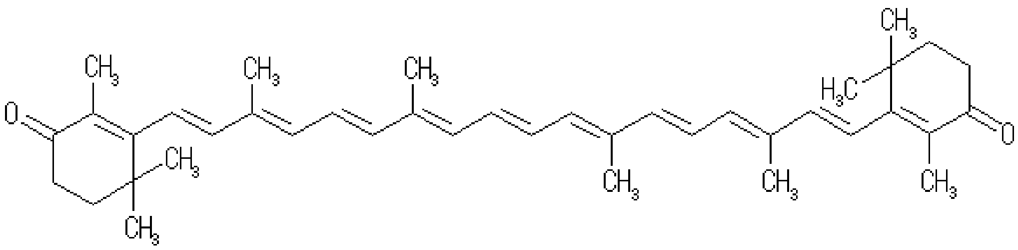

Figure 2. Molecular structure of CX

AS FEED ADDITIVES

In the last 30 years it has been a popular E161g food additive and cosmetic colorant due to its very attractive colour (Esatbeyoglu & Rimbach, 2017). In addition to pharmacological applications (Baker & Gunther, 2004), commercially synthesized canthaxanthin has great impact on food and feed additives (Hari et al., 1997; Kadian & Garg, 2012) mainly in the farming of rainbow trout (Aberoumand 2011; Yesilayer & Erdem, 2011), poultry industry (Graydon et al., 2012), salmonids (Niu et al., 2012) and *Penaeus* cultivation (Hernandez & Blanch, 2000) also. Canthaxanthin is applied for golden-orange pigmentation of broiler skin & egg yolk when used in combination with other yellow pigments like apo esters or yellow xanthophylls like lutein & zeaxanthin. It is also used with pink carotenoids like astaxanthin to colour salmon, trout & ornamental fish species. Canthaxanthin is a permitted feed additive under Council Directive 70/524/EEC and implemented in national legislation by the feeding stuffs regulations for use in feed for trout, salmon and poultry and also for some categories of companion animals (Advisory committee on animal feeding stuffs-ACAF/02/21, 2002). Maximum Residuals Limits (MRLs) for canthaxanthin in different tissues of broiler proposed by European Food Safety Authority (EFSA) are depicted in Table 1. Some popular marketed canthaxanthin and their conventional uses are listed in Table 3.

Table 1. Source: EFSA, 2007; Proposed Maximum Residual Limit in different tissues of broiler

Targeted area	**Proposed MRL (mg/1000g)**
Egg centre	30.00
Poultry liver	15.00
Poultry skin/fat	02.50
Salmon flesh	10.00
Trout flesh	05.00

Product Name	**Origin**	**Routine usage (Web reference)#**
"ColoSence'cantha"	Mumbai, India	To improve augmentation system for poultry & aquaculture (1)
"Natural Canthaxanthin 10% Feed Grade" (Brand Name:FH)	Shaanxi, China	Colouring yolk, chic ken and fish (2)
Roxanthin Red 10 WS	New Jersey, USA	Birds feed additives (3)
"Carophyll Red"	Basel, Switzerland	Mostly colour increase in birds (4)
Leader Red by Guangzhou Leader Bio-Technology Co., Ltd.	China	To pigmenting broiler skin, egg, and salmonids (salmon and trout), *Clarias batrachus*, red tilapia, aquarium fish, crab, etc (5)
PIONEER	Inner Mongolia, China (Mainland)	For animal feed supplements and pharmaceuticals (6)
Lucanthin® Red.	Ludwigshafen, Germany	As chicken feed and fish feed (7)
ONICON	Hubei, China (Mainland)	Used in drink, ice cream, sauce, tomato products, meat products, animal feed additive, make the egg yolk, poultry colour brighter, salmon colour (8)
FLOATING FLAMIGO and GOLD PLUS RED	9800 Deinze, Belgium	To give nice red yolk colour (9)
CANTHAPLUS®10%	Zhongxin Town, Zengcheng,	To concentrate the pigmentation of egg yolk, poultry skin and fish meat (10)

	Guangzhou, China	
XINCHANG	Zhejiang, China (Mainland)	Used in meat products, animal feed additive, make the egg yolk and poultry colour more bright, salmon colour (11)

#1:http://2.imimg.com/data2/AE/SS/MY-2663697/colosence-sensory-feed-colourants-for-animal-nutrition.pdf
2:http://www.xafhbio.com.cn/product/679183057801129084/Supply_Carophyll_Yellow_Powder.html
3: http://hnrca.tufts.edu/wp-content/uploads/Krinsky-Notebook-2.pdf
4: https://icrisma.files.wordpress.com/2013/07/redyellow.pdf
5: https://www.tradeindia.com/fp822482/Leader-Red-Canthaxanthin-10-CWD.html
6: https://www.chemicalbook.com/ProdSupplierGNCB3129988_EN.htm
7: https://nutrition.basf.com/en/Animal-nutrition/Lucantin-Red.html
8: http://onicon.chemdrug.com/
9: http://docplayer.net/amp/36424960-Poultry-feed-for-chickens-turkeys-park-birds-ratites-water-birds.html
10:http://www.feed-additive-technologies.com/public/news_file/Datasheet_201503180859290.pdf
11: https://www.ulprospector.com/en/asia/Food/Detail/16117/391721/Canthaxanthin-Beadlet-10-CWS

USE OF CANTHAXANTHIN IN POULTRY

In animal husbandry field, CX is feed along with the normal foodstuff to contribute the skin and egg yolk a attractive yellowish-reddish colour to enhance consumers priority. Among considerable egg superiority traits, colour falls in third position due to its simple use (Britton et al., 1990). After absorbed by the small intestine, canthaxanthin is carried through blood to hepatic cells from which a portion of captivated CX metabolizes into 4- hydroxyechinenone, isozeaxanthin and 4-oxoretinol (a vitamin A precursor), in both laying hens and broilers. The residual unaffected CX then transferred by 'lipoproteins' through blood towards the accumulation sites where it remains afterwards. Among total feed CX, less than forty percent is accumulated in egg yolk, although the accumulation in the fresh and meat is lesser than ten percent (Rao et al., 2001).
In laying hens, single dose of different carotenoids (20 ppm) as dietary supplements, resulted in significant increase of concentrations of blood plasma. CX concentrations in broiler chicken masses are relational to feeding concentration and are lesser than ten percent of eating which shows a linear relationship among the CX strength found in the chicken hepatic cell (mg/kg) and the amount fed to the test group over their food (mg/kg). The deposition of canthaxanthin in egg yolk is directly proportional to dietary level (Zhang et al., 2011).
Egg yolk colour ordinarily compared with unique colour charts matching with altered intensities of coloration (from 'light yellow to orange and red'). The utmost used is the "Roche Yolk Colour Fan" (RYCF) displaying a scale from one (light yellow) to fifteen (red orange). Typical exercise for the CX concentration in a standard food regime might be between two and six mg/ 1000g of feed. However, selected contemporary reports indicated that nutritional supplementation ratio increase up to 10 fold than suggested intensities is harmless for 'broilers', 'laying hens' and 'poultry breeders' without any harmful effects (Weber et al., 2013; Rosa et al., 2012; Surai et al., 2016). Canthaxanthin can reduced the thiobarbituric reactive substances in eggs (lipid peroxidation rate reduced) thus improved the fertility and hatchability rate of broiler breeders (Surai et al., 2016).

Other important influences of canthaxanthin in broilers include improvement in breeding performance, chick quality performance and antioxidant status (Rosa et al., 2012), egg hatchability (Moller et al., 2000), immune function (McGraw & Hill, 2006), regulation of cell differentiation and proliferation etc. (Surai et al., 2016).

Distinctive elements such as ‘feed composition’, ‘carotenoids interaction’ and ‘health status’ of the test subject may disturbs CX accumulation in the egg yolk and might justify the unpredictability of the results observed (Costantini & Moller, 2008).

USE OF CANTHAXANTHIN IN FISHERY

Frequent findings have disclosed that the configuration of the feedstuff and its energy content straightforwardly disturb the bodily state of fish although they are incapable of synthesizing carotenoids de novo and as a result dietary supplement is mandatory by mixing CX into their foodstuff (Torrissen et al., 1990; Choubert & Baccaunaud, 2006). After ingestion, CX mainly captivated in the middle and terminus portion of the intestine (Ando et al., 1985). Then CX is shipped by lipoproteins (Foss et al., 1984). The engagement and dissemination of carotenoids in fish flesh is persuaded not only by species but also by ‘age’ and ‘physical state’, ‘food type’, and the ‘environment inhabited’ by the fish (Hencken 1992; Clydesdale 1993).

Fish complexion is enhanced by reddish carotenoid pigments from light to dark where conventionally coloration is interrelated to loftier flavour (Baker et al., 2002)]. Fish flesh having balanced consistency and shrill colour may motivate consumer to pay hefty prices than normal. The highest often used mechanical colour measurement are the ‘CIE [1976] L*, a*, b*,’ and the ‘Hunter L, a, b systems’, which key factors are ‘lightness (L*)’, ‘redness (a*)’ and ‘yellowness (b*)’. Lately proper methodical approaches to analysis the consequences of altered nutritional ingredients like ‘minerals’, ‘micronutrients’, ‘fatty acids’, ‘vitamins’ and ‘carotenoids’ etc. has been applied in few cultivated fish like ‘salmonids’, ‘rainbow trout’, ‘carp’ or ‘red sea bream’ (Kiessling et al, 2003). After supplementation of very minute concentration of carotenoids through diet to ‘Atlantic Salmon’ along with CX, results revealed that CX and its conjugates endorsed fourteen percent and seventy percent of total carotenoids, respectively. The tested sample was ‘Atlantic Salmon’ skin tissue (Page & Davies, 2006).

Canthaxanthin is predominantly dumped in the meat of ‘salmonids’ as it binds to ‘myofribrillar actomyosin’ although undeveloped ‘rainbow trout’ amasses ten percent of the engrossed carotenoids (nearly) in the skin (Page & Davies, 2006). Reports on ‘rainbow trout’ in ‘freshwater’ and ‘saltwater’ have revealed that the CX intensity in the meat of undeveloped trout amplified when the dietetic carotenoid strength was amplified, however depressed when dietary concentration is increased over 200mg/kg feed (Bjerkeng et al., 1992; Page & Davies, 2006). Distinctive parameters like captivation of dietary CX in ‘salmonids’, ‘interaction with vitamin A, E’ and ‘sexual maturation’ disturbs canthaxanthin accumulation in the fish meat enlightening wide variation in experimental outcomes. On different study, “a suggestive development in colour and pigment may be observed in freshwater and marine ornamental fish, such as ‘tetras’, ‘cichlids’, ‘gouramis’, ‘goldfish’, ‘koi’, ‘danios’, ‘swordtails’, ‘rosy bards’, ‘rainbow fish’, ‘discus and clown anemone fish’”etc. (Lorenz & Cysewski, 2000).

Other than colour intensification (Li et al., 2013), reports suggest that keto-carotenoid like CX may also impair with development and reproductive physiology of fish (Torrissen & Christiansen1995). Presence of these compounds ingested by fish via their diet, contributes to an increased number of immune bodies in their metabolic pathway. They moreover show an imperative character in fish reproduction as they have a beneficial effect on spawning performance, depress larval mortality, and enhance growth rate (Guroy et al.,2012).

Carotenoids like canthaxanthin ought to be considered as a vitamin for fish and their diets must be intensified with dry feed at a safe level to ensure the well-being of the animal, though connections among 'fish size' and 'pigment level' are yet to be uncovered (George et al., 2001).

Various studies have been done in this area with successful findings.

FUTURE SCOPE

CX is a very strong pigment even in miniature quantity level. In European Union, carotenoids like CX is generally treated and approved as only "sensory additives" as colour additives (Bera et al., 2015, 2017, 2019) We are now in an age where colour of a food makes a vast difference in consumer choice and demand. Additionally, consumer's awareness is now inclined towards natural products with bioactive properties instead of synthetic ones (Bera et al., 2017, 2019). Hence pigments like CX gaining additional attention due to its strong antioxidant activity and bioavailability (Mitra et al, 2017a & b). Proper exploration of natural sources for CX is required to meet the demand for natural dyes. Also it shall be great help in pharmacological industry where chemical colorants are being reported everyday due to their various side effects (Mitra & Dutta, 2019). As a result, CX may be a potential natural candidate of nutraceutical and pharmaceutical importance in future.

CONCLUSION

The present article concludes that canthaxanthin could be established as a potent carotenoid having potential nutraceutical and pharmaceutical benefits. However, more clinical studies are required to establish this molecule as a potent bioactive agent. Also, sources for this molecules still now not fully explored. As a result, scarcity for required quantity is still an annoyance. Researches made in current decade on canthaxanthin might help to spread some beam of hope upon the the need of pharmaceutically important bioactive compound hunt.

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