Can Poor Nutrition Influence Psittacine Feather Pigmentation?

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Introduction

Aberrations in psittacine feather pigmentation are not commonly associated with dietary intake. However, there are several stages in the conversion of pigmentation precursors to psittacofulvin pigments and consequent linkage to keratinous amino acids. Disruption of any one of these processes could contribute to poor feather colouring in psittacines. Dietary influences on feather pigmentation in psittacines are summarised.

Psittacine Feather Colour

Psittacine feather colour can be divided into three main groups:

- Blue – from refraction/reflection of light on melanin pigments
- Green – from a combination of refraction/reflection of light on melanin pigments overlain by yellow pigment
- Yellow/orange/red – from production of psittacofulvins

Blue Feathers

The production of blue feathers results from the reflection/refraction of light on melanin pigments that lie within a matrix of granules, overlaying keratin. Melanin is formed by the hydroxylation of tyrosine to dihydroxyphenylalanine (DOPA), followed by the formation of quinone, and complex condensations to form pigments. The initial oxidation reactions of tyrosine to DOPA-quinone are catalysed by tyrosinase with the cofactor copper. Tyrosinase activity may be diminished in birds fed copper or lysine-deficient diets. Cockatiel feathers lacking melanin are also associated with dietary deficiencies of choline or riboflavin

Green Feathers

Green feathers are produced from a combination of refraction/reflection of light on melanin pigments that are overlain by yellow psittacofulvin pigments. Therefore, alterations to green feathers can result from disruption of the melanin pigments or production of yellow psittacofulvins. If the production of melanin is compromised, normally green coloured feathers may become yellow. More commonly, feathers that are normally green develop dark areas, appearing to lack pigmentation altogether. This could be influenced by the production and anchoring of psittacolfulvins in the feather.

Yellow/Orange/Red Feathers

Psittacofulvins are responsible for yellow, orange and red feathers in psittacines. These polyenal pigments are aldehydes derived from fatty acid metabolism of at least 18 carbons. An increase in the fatty acid chain length changes the feather colour from yellow to orange to red, with an increase in the number of unsaturated bonds increasing the intensity of the colour. A negative impact on fatty acid metabolism may ultimately affect availability of polyenal precursors.

Site of Synthesis of Psittacofulvins

In contrast to the exogenously sourced carotenoids of passerine feathers, psittacofulvins are endogenously synthesized within the mature feather follicle similar to the synthesis of melanin by melanocytes within feather tracts. Various carotenoids have been measured circulating in the blood of psittacines and there appears to be mechanisms for absorbing carotenoids, but it is plausible that binding-site specificity of intracellular proteins preferentially keratinize psittacofulvins over carotenoids. In the absence of sufficient production of psittacofulvins, it is possible that absorption of carotenoids result in paler feather colours due to structural differences at the tertiary and quaternary levels of proteinaceous keratin of psittacine feathers compared to those of passerines.

Polyenals Require Antioxidant Protection

Polyenals themselves are highly unstable, requiring antioxidant protection. Diets low in antioxidants such as carotenoids, vitamins E and C, Se and Zn, may destabilise the polyenal structure, resulting in poor pigmentation. Some pesticides disrupt the micelle structure necessary for the uptake of vitamin E, preventing antioxidant protection of polyenal precursors. Excesses of vitamin A from formulated diets or dietary supplements can also minimise uptake of vitamin E.

Keratin

Once the polyenal pigment has been produced by the feather shaft and deposited in the feather it is attached to keratin. For keratin to link to the polyenal pigment, it must contain dibasic amino acids (histidine, lysine or arginine) that are positively charged (free nitrogen). While these amino acids are positively charged at physiological pH, any significant increases in pH can remove the positive charge and prevent bonding with the polyenals. A dietary deficiency of essential dibasic amino acids can also impact bonding between keratin and polyenals.

$$\left.\begin{array}{r} CH_3\text{-}(CH{=}CH)_n\text{-}CH{+}N^{+}\text{-} \\ \\ \text{-}OOC \end{array}\right\} \text{Keratin}$$

Protein Structure of Feather Keratins

There are four levels of protein structure that are distinguished by the nature of the bonds and the interactions that stabilize each level of structure. The *primary* structure is defined by the sequence of peptide-linked amino acids. The linear sequence dictates the types of interactions that can occur between side chains as the protein folds into higher orders of structure. The peptide bonds that form the backbone of the protein profoundly influence the *secondary* structure that is characterised by repeating structures that permit rotations in the polypeptide backbone. This structure is stabilised by hydrogen bonds that are formed between the carbonyl oxygen atom of one peptide bond and the amide hydrogen of another.

The three major *secondary* structures in proteins are: α-helix, β-sheets and β-bonds. α-keratins commonly found in feathers are rich in cysteine and cystine residues and tend to form an α-helix. If the basic amino acids arginine and lysine are found side by side, their positive charges can repel each other and prevent the formation of the α-helix, disrupting the bonding of psittacofulvins to keratin.

It is at the *tertiary* and *quaternary* levels of protein structure that psittacine feathers differ from those of passerines. The *tertiary* structure refers to the overall three-dimensional arrangement of the polypeptide chain. The structure is stabilised by hydrogen bonds, ionic bonds and hydrophobic interactions between amino acid side chains. Not all proteins have subunits but those that have more than one polypeptide chain have a *quaternary* structure.

Vitamin A and Keratin

Hyperkeratosis generally results from the drying out and gradual hardening of epithelial cells to form keratin. Both dietary deficiencies and excesses of vitamin A are correlated with hyperkeratosis. It is possible that deficiencies or excesses of vitamin A interfere with the formation of keratin in feathers, thus preventing bonding to psittacofulvins.

Summary

In summary, feather pigmentation or intensity of feather colour can be altered by:

a) inappropriate dietary fatty acids (precursors to polyenals)
b) interference with fatty acid metabolism
c) disruption to enzymatic conversion of fatty acids to polyenals
d) dibasic amino acid deficiency (influences bonding of polyenals to keratin)
e) insufficient antioxidants to protect fatty acids or polyenals
f) insufficient or excess vitamin A (disrupts keratin formation).

Acknowledgement

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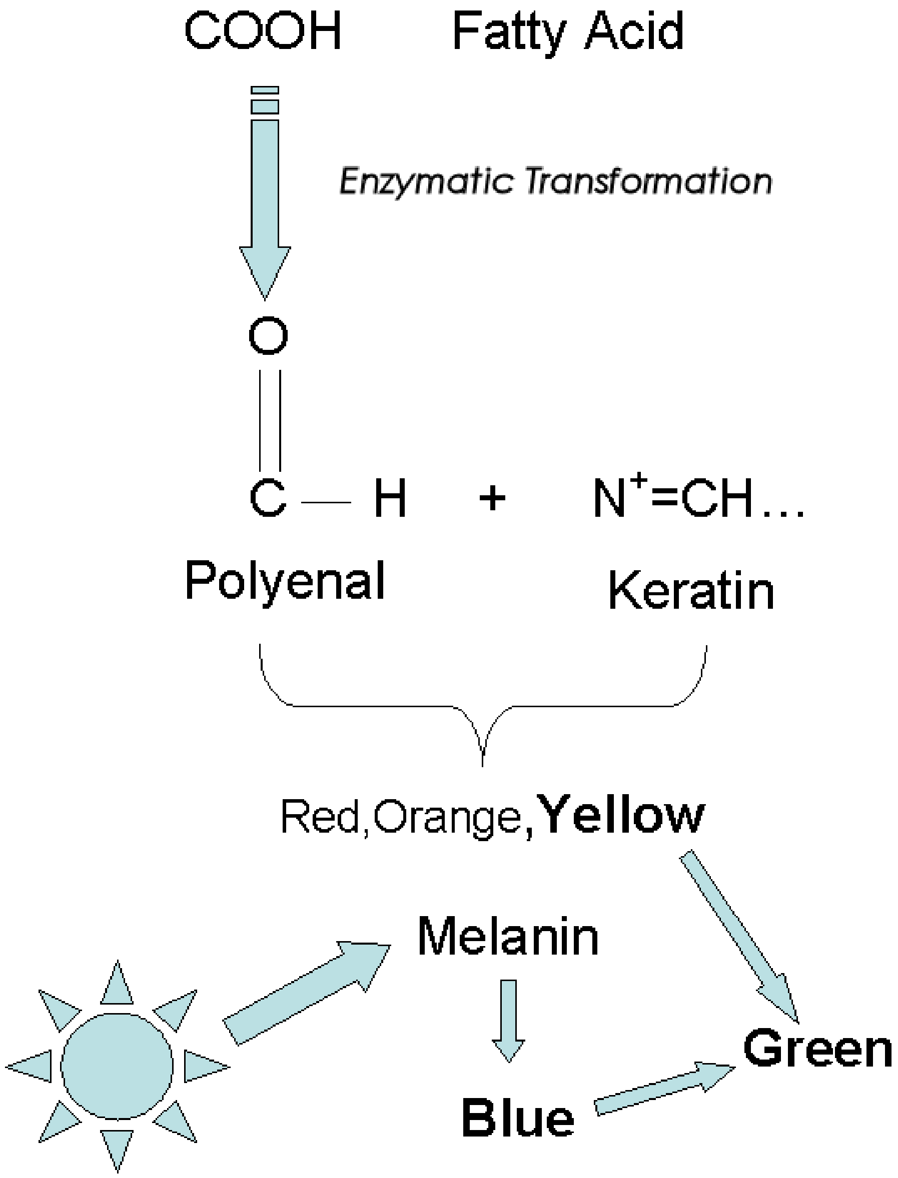

Figure 1. Biochemical pathways for psittacine feather pigmentation.