Abstract

In the late 1980s, polyunsaturated fatty acids (PUFAs) of the ω-6 and ω-3 families were recognized as essential nutrients to human and animal health. The Columbus concept—a clearly defined proposal towards a return to the “wild-type” ω-6:ω-3 fatty acid ratio in the fat depots of modern livestock—had led to the development of the Columbus egg. This egg serves as prototype for the design of other “wild-type” animal-derived products (dairy and meat products) as well as of functional ω3 long-chain (LC)-PUFAs enriched Columbus eggs.

This chapter presents and discusses the range of raw materials that are commercially available for layer feed used in the production of the original “wild-type” Columbus eggs and the feed supplements that can be used to design a second generation of ω-3 LC-PUFAs enriched Columbus eggs.

Key Words: Feed ingredients; n-3 PUFAs; egg yolk.

1. INTRODUCTION

In the 1960s and 1970s, the correlation between blood cholesterol—considered at that time as a biochemical marker for cardiovascular diseases—and the contribution of dietary cholesterol, saturated and unsaturated fatty acids in the daily food supply was demonstrated (1). A decade later, the importance of the contribution of the two families of ω-6 and ω-3 polyunsaturated fatty acids (PUFAs) to the human health in the long run started to attract scientific interest (2). Today, the ratio of ω-6:ω-3 fatty acids in the diet seems to be one of the most important parameter to follow-up.

Mammals, including humans, are unable to synthesize linoleic acid (C18:2ω6 or LA) and α-linolenic acid (C18:3ω3 or ALA). Hence both fatty acids are said essential and must be present in the diet. Long-chain PUFAs (LC-PUFA) can be derived from LA and ALA, however the conversion is limited with yields typically ranging from 10 to 30% depending upon their respective concentration in the diet and other genetic, environmental, and physiological factors. The metabolic pathway is common to both families of essential fatty acids and involves a series of desaturases and elongases (see Table 1). The most important LC-PUFAs generated from these pathways are arachidonic acid (C20:4ω6 or ARA) of the n-6 series, eicosapentaenoic acid (C20:5ω3 or EPA) and docosahexenoic acid (C22:6ω3 or DHA) of the n-3 series (3).
An alternative way to fish to providing consumers sufficient amount of ω-3 LC-PUFAs in the diet is to incorporate ALA in the feed components of modern livestock. Most domesticated animals do at least partially process ALA into ω-3 LC-PUFAs. Whereas the former is preferentially deposit into intramuscular fats and fat depots of the animals, the latter are mostly found in their tissue phospholipids. Therefore, a number of limitations applied to the design of “wild-type” animal-derived consumer products:

- In pork, genetic selection has allowed to design extremely lean meats (less than 2% intramuscular fat) which catch consumer preference. High quantities of ALA in the feed render the bacon of the loin softer, thus creating difficulties during meat-processing; yellowing of the fat is another risk.
- In dairy products, hydrogenation in the rumen inhibits the transfer of ω-3 fatty acids from the feed into milk. Some alternatives have been developed to render ω-3 sources resistant to the rumen. When the milk fat is higher in PUFAs, then the butter produced from it has a higher melting point.
- In poultry meat, the amount of PUFAs in the fat of the chicken carcass can be readily influenced by nutritional means. Therefore, broiler is a good potential source of ω-3 LC-PUFAs. Sufficient attention must be drawn to the stabilization of such meat in order to avoid early development of rancid or fishy taste and smell.
- In eggs, many studies have examined the possibility of transferring ω-3 fatty acids from layer feed to egg triglycerides and phospholipids, and the results are most promising.

### 2. INGREDIENTS FOR COLUMBUS FEED

The total lipid fraction of the Columbus egg is characterized by P:S and ω-6:ω-3 ratio’s close to 1:1. For the sake of comparison, the lipid fraction of ordinary eggs exhibits a P:S ratio of ±1:2 and a ω-6:ω-3 ratio of ±9:1. An increase in the fat content of the layer feed results in the inhibition of the novo-synthesis of yolk fat, a natural process by which yolk fat can easily be manipulated. In designing the Columbus feed, it is critical that all raw materials of the ration be considered for their eventual influence on the P:S and ω-6:ω-3 ratio’s. To that end, the most important raw materials commercially available for layer feed will be discussed. In general terms, the raw materials used for the Columbus feed greatly differ from those of a classic layer feed. A survey of the raw materials available in different parts of the world (e.g., cereals, leguminosae,

### Table 1: Essential Fatty Acid Metabolic Pathway

<table>
<thead>
<tr>
<th></th>
<th>C18:3</th>
<th>C18:2</th>
<th>C18:3</th>
<th>C20:4</th>
<th>C20:4</th>
<th>C22:5</th>
<th>C22:5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALA</td>
<td>Δ6-Desaturase</td>
<td>C18:2</td>
<td>C18:3</td>
<td>C20:3</td>
<td>C20:4</td>
<td>C22:4</td>
<td>C22:5</td>
</tr>
<tr>
<td>EPA</td>
<td>Δ5-Desaturase</td>
<td>C18:2</td>
<td>C18:3</td>
<td>C20:3</td>
<td>C20:4</td>
<td>C22:4</td>
<td>C22:5</td>
</tr>
<tr>
<td>DHA</td>
<td>Δ4-Desaturase</td>
<td>C18:2</td>
<td>C18:3</td>
<td>C20:3</td>
<td>C20:4</td>
<td>C22:4</td>
<td>C22:5</td>
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</tbody>
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