Depletion of ascorbic acid derivatives in fish feed by the production process

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ABSTRACT: The depletion of ascorbic acid derivatives in fish feed during the feed processing (extrusion cooking and drying) was studied at five extrusion cooking temperatures and at 85°C for 2 h dryer processing temperature. Three ascorbic acid derivatives were used: L-ascorbyl-2-mono-phosphate Mg (APM), L-ascorbic acid sodium (AAS) and L-ascorbic acid palmitic acid ester (AAP). Samples were collected after drying and ascorbic acid derivatives losses evaluated. APM was found to be quiet stable with an average retention of 88%, but AAS and AAP were unstable and the depletion was very high.

KEY WORDS: ascorbic acid, ascorbic acid derivative, extruded pellet, extruder, extrusion cooking, heat damage, heat stability.

INTRODUCTION

In the field of fish feed, extruded pellets (EP) are popular worldwide. In salmon and trout culture, almost all feed is EP. The EP are produced by an extruder with a single or twin shaft at high temperature and pressure. In general, EP comprise fish meal, cereals, vegetable protein, oil-seed meal, and microingredients. Microingredients suggest minerals, vitamins and pigments and they generally have a low heat stability.

The use of L-ascorbil-acid-2-mono-phosphate Mg (APM) for fish feed is common because it has high heat stability and good preservative qualities in feed due to the protective role of its phosphoric acid radical against oxidation-reduction at its position on the molecule and to its titer being as the same as ascorbic acid. However, its cost is very high compared with other ascorbic acid derivatives and even only 50 ppm added to feed would be a reason for a price increase. L-ascorbic acid sodium (AAS) and L-ascorbic acid palmitic acid ester (AAP) are popular in food engineering and both AAS and AAP are in feed for vitamin enrichment and antioxidation, for example, to keep the color, flavor, texture etc. but they do not have high heat stability like APM.

During the manufacturing process of EP heat sensitive materials, such as vitamins and pigments, are highly damaged. Some heat-resistant vitamins are coated by hydrogenated oil, but they are not so effective against high temperature and pressure in extruder. This study examined the heat stability of ascorbic acid derivatives in EP during feed processing at various extrusion cooking temperatures by using a twin-shaft extruder.

MATERIALS AND METHODS

Ascorbic derivatives

Three ascorbic acid derivatives were used for the experiment. L-ascorbil-2-mono-phosphate Mg (APM; Phospitan C, Showa Denko K. K., Tokyo, Japan), L-ascorbic acid sodium (AAS; Wako Pure Chemical Industries, Ltd, Osaka, Japan) and L-ascorbic acid palmitic acid ester (AAP; Yokohama Oils & Fats Industry Co., Ltd, Yokohama, Japan).

Feed formula

The formula of the experimental pellet is shown in Table 1 and is referred to as Salmonid feed of Nippon Suisan Kaisha Ltd. (Tokyo, Japan). Brown fishmeal was made of Chilean horse mackerel and was imported from Chile. Wheat flour was of feed grade by Showa Sangyo Co. Ltd. (Tokyo, Japan). Soybean defatted meal was of feed grade by Nissin Oil Mills Ltd. (Tokyo, Japan). Cassavas starch was from Nippon Starch Chemical Co. Ltd. (Osaka, Japan).
Ascorbic derivatives were added to the formula at 10-fold more than the usual amount for fish feed for analytical accuracy. AAP is authorized as a food additive in Japan, but not as a feed additive. However, AAP is popular in the food industry because of its high heat stability, and so it was used as a reference in this study.

**Experimental extruder**

A Suehiro EPM (Yokkaichi, Japan) Alpha 50 (screw diameter 68 mm, screw length/diameter = 20) was used as an experimental extruder as shown in Fig. 1. The screw rotation was set at 120 rpm and the die diameter was 5 mm. The screw configuration was all forward pitch screw. Table 2 summarises the temperature of the extruder barrels and the die head for each experiment. Except for the die head and the No. 1 barrel, the temperature of each barrel was controlled by electric heating and water cooling. The die head and the No. 1 barrel have only water cooling. The experimental samples after extrusion cooking were dried immediately at 85°C for 2 h in a hot air dryer (AL-10C, Asahi Kagaku Co. Ltd, Saitama, Japan).

**Analysis of ascorbic acid derivatives**

Japan Food Research Laboratory (Tokyo, Japan) analyzed the ascorbic acid derivatives in EP concurrently by using the high-performance liquid chromatography analytical method. AAP was authorized as a food additive in Japan, but not as a feed additive.

**Moisture**

Moisture was measured by using an infrared moisture meter (PD2–300WMB, Chyo Balance Corporation, Kyoto, Japan). Table 3 shows the moisture of each sample after drying; the moisture was 4.9–7.7%.

**RESULTS**

The variation of material temperature in the extruder, main motor amperage for the shafts, and the material pressure in the extruder with extrusion cooking were measured by thermocouples and pressure sensors as shown in Fig. 1. Table 2 shows the temperature of each barrel of the extruder and Table 3 shows the moisture of each sample after drying.
Depletion of AA derivatives

The extrusion cooking condition is severe for some low-heat stability additives, such as vitamins and pigments,\textsuperscript{4-13,17} because the extrusion cooking is at more than 30% of raw material moisture, more than 30 kg/cm\textsuperscript{2} of extrusion cooking pressure, and about 100°C of raw material temperature.\textsuperscript{2-4} After cooking, the pellets are dried in a dryer at about 80°C for 1 h.

In the feed industry, APM is popular and has a history of good performance. No heat depletion occurred during the preset experiment. This confirms previous findings on L-ascorbyl-2-poly phosphate Mg and on APM by Gadient \textit{et al.}\textsuperscript{6} and Anderson \textit{et al.}\textsuperscript{4} Conversely, the heat of AAS and AAP was depleted considerably, especially, the depletion of AAP was extreme. Despite this, AAP is useful for oil and fat products in the food industry and is also used in frying oil as an antioxidant.

In a conventional feed plant, the method of mixing ascorbic acid into the feed before extrusion cooking requires APM. Some ascorbic acids are coated by hydrogenated oil and fat, but they have insufficient heat stability against extrusion cooking.

Recently, some machine manufacturers have offered a new method of adding vitamins to feed by using a vacuum coater and infusion system. For example, in the process of oil coating after drying, an emulsified oil with vitamins or pigments can be added to the feed. This is an interesting way to keep heat-sensitive materials from heat damage, and AAS and AAP can be used. Today, APM is recommended for feed produced by extrusion cooking. However, when vacuum coating becomes more popular, AAS and AAP in pellets would be used.

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REFERENCES

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Table 4  Change in ascorbic acid derivatives (mg/100g) after extrusion cooking and drying

<table>
<thead>
<tr>
<th></th>
<th>Before extrusion cooking</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>APM</td>
<td>41</td>
<td>29</td>
<td>33</td>
<td>38</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>AAS</td>
<td>49</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>AAP</td>
<td>41</td>
<td>ND</td>
<td>ND</td>
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<td>ND</td>
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</tr>
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</table>

ND, none detected. The detection limit of the method of analysis was 1 mg/100g.

Fig. 2  Variation of material temperature in extruder, main motor amperage for shafts, and material pressure in extruder with extrusion cooking temperature; (○), Material temperature 1; (△), Pressure; and (□), Main motor amperage. The temperature of No. 5 barrel represents the extrusion cooking temperature.


