INNOVATIVE USE OF NORI (SEAWEED) IN FUNCTIONAL FOODS AND COSMETICS

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ABSTRACT

Purple laver (Nori, Porphyra yezoensis and ββ) is the most largely cultured seaweed in Japan. Annually, Nori is produced about 400,000 tons (wet basis) and 100 billion yen (1 billion US$) and one of the most important components of Japanese food. Nori contains many of the nutritionally functional components, such as β-carotene, porphyran and vitamin B12 etc. However, Japanese Nori culture industry is now facing problems such as down trend of average price, competition with foreign countries and low quality appearance. We are studying functional ingredients of Nori for cosmetics and functional foods to add value to Nori and to develop new utilization ways of Nori. In this paper, we introduce two studies about functional compounds of Nori, one is about UV-absorbing amino acids (mycosporine-like amino acids) as cosmetic ingredients, and another one is about glycerol galactoside, which has prebiotic activity, as functional foods material.

Keywords: Nori, Porphyra, purple laver, mycosporine-like amino acids (MAA), Glycerol galactoside, prebiotics

INTRODUCTION

Purple laver (Nori, Porphyra yezoensis and Porphyra tenera) is the most largely cultured seaweed in Japan. Annually, Nori is produced about 400,000 tons (wet basis) and 100 billion yen (1 billion US$) and one of the most important components of Japanese food such as sushi. Nori is largely consumed in East and Southeast Asia, and due to the recent popularity of sushi, it is now available in many countries. Nori contains many of the nutritionally functional components, such as β-carotene, porphyran and vitamin B12, (Mumford and Miura 1988). There are many papers reporting about nutritional functions of nori and its components, such as antitumor (Noda et al. 1989), immunostimulating (Yoshizawa et al. 1993), anti-allergic (Ishihara et al. 2005), anti-oxidant (Zhang et al. 2003), enhancing dioxin excretion (Morita and Tobiishi 2002) and antimutagenic (Okai et al. 1996) effects. However, Japanese Nori culture industry is now facing problems, e.g. down trend of average price, competition with foreign countries and low quality appearance. We are studying functional ingredients of Nori for cosmetics and functional foods to add value to Nori and to develop new ways of utilizing Nori. In this paper, we introduce two studies about functional compounds of Nori, one is about UV-absorbing amino acids (mycosporine-like amino acids) as cosmetic ingredients.

Mycosporine-like amino acids (MAA) can absorb harmful UV irradiation from sunlight and convert it into harmless heat (Conde et al. 2004). MAA are thought to be promised compounds as cosmetic ingredient. We found a new functionality of these amino acids (promotion of skin fibroblast proliferation) and developed a new cosmetic product.

Another study is about glycerol galactoside (GG). GG is contains a large amount of low quality
Nori, and only a small amount of normal quality Nori. We have found that when orally administered, GG can increase intestinal bifidobacteria (prebiotic activity) (Muraoka et al. 2008, Ishihara et al. 2010). We are now developing a new material containing GG for functional foods.

**Mycosporine-like amino acids in Nori as a cosmetic ingredient**

**Mycosporine-like amino acids**

Mycosporine-like amino acids (MAA) are natural amino acid derivatives having absorption peaks in the UVB (280-320 nm) and UVA regions (320-400 nm), and are synthesized by cyanobacteria, algae, fungi, and bacteria (Bandaranayake 1998; Dunlap and Shick 1988, Shick and Dunlap 2002). MAA are widely distributed in aquatic organisms including invertebrates and fishes via food-chain. MAA are thought to act as natural UV sunscreen in these marine organisms and are promised compounds for cosmetic uses.

**Functions of MAA in Nori**

In Nori, we found three major MAA (porphyra-334, shinorine, palythine) (Fig. 1). We analyzed MAA content and found that MAA content was around 1% by dry basis. MAA content positively correlated with protein content of Nori (Fig. 2). Protein content is used as an index of quality of Nori. Therefore, it was suggested that high-quality Nori contains high amount of MAA.

MAA are thought to act as natural sunscreen in aquatic organisms. We examined sunscreen effect of MAA on human fibroblast and found MAA to have strong sunscreen activity (Oyamada et al. 2008). We have also found growth promoting effect of MAA on human skin fibroblast. These activities are suitable for functional cosmetic ingredients.

**Development of a skin care product containing Nori extract**

We have developed a new skin care product in collaboration with a cosmetic company. We have developed Nori extract which contains MAA. Nori was pulverized and extracted with solvent and filtered through activated charcoal column for deodorization and decolorization. We obtained light brown colored extract. We confirmed the activities of Nori extract (Fig. 3 and Fig. 4). Nori extract contains MAA protected human skin cells from UVB-induced cell death. Nori extract also promotes fibroblast growth. Finally we developed a new skin care product blended with the Nori extract.

**Glycerol galactoside in low-quality Nori as a functional food material**

**Glycerol galactoside in low-quality Nori**

During studies about utilization of low-quality Nori, we found that low-quality Nori was fermented very well by lactic acid bacteria. We hypothesized that low-quality Nori contained growth-
Fig. 2. Relationship between mycosporine-like amino acid content and Total protein content in Nori samples with different quality.

\[ y = 0.0264x + 0.2865 \]
\[ R^2 = 0.6572 \]

Fig. 3. Protective activity of Nori extract containing mycosporine-like amino acids on human skin cells from UVB irradiation. Cell survival after UVB irradiation (50 mJ/cm²) was measured. V.C.: Vitamin C.
promoting substance for lactic acid-bacteria, and purified and identified the substance as glycerol galactoside (GG; floridoside: 2-O-glycerol-α-D-galactopyranoside, and isofloridoside: 1-O-glycerol-α-D-galactopyranoside, Fig. 5). Already, GG has been known to be a component of nori (Noda et al. 1981). But we found low-quality Nori have large amount of GG while normal-quality Nori contains relatively small amount of GG (Fig. 6). GG was selectively utilized by bifidobacteria among intestinal bacteria in vitro. GG was not digested by digestive enzymes and also not adsorbed via intestinal wall in vitro. Thus we concluded GG possibly have a prebiotic activity (Muraoka et al. 2008).

Prebiotic activity of GG

Prebiotic activity of GG was confirmed in vivo by an animal experiment. Rats were fed with 5% GG supplemented diet for two weeks (fructooligosaccharide (FOS) supplemented diet was used as positive control). The GG diet increased intestinal bifidobacterial count and lactobacillus bacteria although the degree of the increase of bifidobacteria was less than that of FOS-diet group (Table 1). From this experiment, GG was suggested to have a prebiotic activity in vivo.

Synergistic effect of GG with porphyran, a major component of Nori

At first, we attempted to use purified GG as a functional food ingredient. But in terms of cost, it had turned out that purified GG was not competitive to other commercial prebiotic products. Thus, we thought that we should study to use GG as low-quality Nori itself or a crude extract. If there are any synergistic effects of GG with other Nori components, they can be an advantage for use of Nori itself or crude extract.

Nori contains porphyran, a sulfated polysaccharide, as a major component. Porphyran is known as dietary fiber and reported to stimulate immunity (Yoshizawa et al. 1993). We evaluated synergistic effect of GG and porphyran on intestinal immunity and fecal excretion in mice. GG showed little or no effects both on intestinal immunity (Cecal Immunoglobulin A (IgA) conc., Fig. 7) and fecal excretion (Fig. 8). But GG synergistically augmented IgA and fecal excretion elevating effects of dietary porphyran. These synergistic effects of GG and porphyran can raise a value of low quality Nori and crude extract of Nori which contains GG and porphyran as a functional foodstuff. Now we are developing a new functional food material made of Nori extract which contains both GG and porphyran.
Fig. 5. Structure of glycerol galactoside (floridoside: 2-O-glycerol-\(\alpha\)-D-galactopyranoside, and isofloridoside: 1-O-glycerol-\(\alpha\)-D-galactopyranoside).

Fig. 6. Relationship between glycerol galactoside content and Total protein content in Nori samples with different quality.

Table 1. Cecal microflora in rats fed FOS* and GG* diets.

<table>
<thead>
<tr>
<th>Group</th>
<th>Control</th>
<th>FOS</th>
<th>GG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactobacillus</td>
<td>8.65 ± 0.15(^a)</td>
<td>8.78 ± 0.06(^a)</td>
<td>9.11 ± 0.05(^b)</td>
</tr>
<tr>
<td>Bifidobacterium</td>
<td>6.07 ± 0.32(^a)</td>
<td>8.69 ± 0.21(^b)</td>
<td>7.16 ± 0.27(^c)</td>
</tr>
<tr>
<td>Bacteroides</td>
<td>7.95 ± 0.09</td>
<td>7.71 ± 0.09</td>
<td>7.72 ± 0.04</td>
</tr>
<tr>
<td>Clostridium XIV</td>
<td>9.35 ± 0.07</td>
<td>9.44 ± 0.12</td>
<td>9.07 ± 0.111</td>
</tr>
<tr>
<td>Enterococcus</td>
<td>6.73 ± 0.17</td>
<td>6.92 ± 0.12</td>
<td>7.11 ± 0.06</td>
</tr>
<tr>
<td>Total Bacteria</td>
<td>10.10 ± 0.08</td>
<td>10.22 ± 0.12</td>
<td>9.95 ± 0.10</td>
</tr>
</tbody>
</table>

Data are expressed as Log CFU/g cecal content.

*: FOS: Fructooligosaccharide, GG: Glycerol galactoside

Values not sharing a common superscript are significantly different by Tukey’s HSD test.
Fig. 7. Effect of glycerol galactoside and porphyran supplemented diets on cecal IgA concentration in mice. Statistical difference was analyzed by two-way ANOVA. GG: P = 0.029*, Por: P < 0.0001*, GG x Por = 0.048*

Fig. 8. Effect of glycerol galactoside and porphyran supplemented diets on fecal excretion in mice. Statistical difference was analyzed by two-way ANOVA.
CONCLUSION

Nori is a major component of Japanese foods which contains many attractive functional components. We think Nori potentially can be a new material for functional cosmetics and foods. In this paper, we introduced two studies about functional components of Nori. In Japan, many projects to develop new utilization ways of Nori are in progress. We believe that there are new products which can be made using functional components of Nori in near future.

REFERENCES