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Note

Alcohol Fermentation of Green Banana

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This paper reports that heating of green (immature) banana fingers at around 80°C for 30 min greatly improves the digestibility of the banana starch by glucoamylase and results in good alcohol fermentation by yeast. The addition of pectic enzymes accelerates the alcohol fermentation.

Banana for export is generally green. Before export it is subjected to strict investigation to prevent damage, and a substantial amount of green banana is removed and discarded as a waste at the entrepot. The total content of carbohydrate of green banana (flesh and rind) is more than 25% by weight and the major component is starch. However, the starch of green banana is hard to saccharify by amylolytic enzymes. Mashing of green banana causes results in a sticky brownish material. The present paper reports that heating of green banana at around 80°C makes the banana starch sensitive to amylolytic enzymes and allows it to be fermented by yeast completely.

Materials and Methods

Green banana The green banana hands examined were the product of Mindanao, the Philippines, and were kindly supplied by Kobe Branch of Sumitomo Shoji Co., Ltd.

Enzymes Glucoamylase and pectic enzymes used were commercial preparations (Hankyu Kyoei Bussan Co., Ltd., Osaka), derived respectively from the solid cultures of *Rhizopus* sp. and *Aspergillus niger* on wheat bran. The glucoamylase preparation had 6000 units of activity per g, of which one unit was defined as the activity that produced 10 mg of glucose on incubation for 30 min at pH 5.0 and 40°C in 1.0% soluble starch solution. The activity of the pectic enzyme preparation was 6000 units, of which one unit was defined as the amount of enzyme that caused a half reduction of the viscosity of 10 ml of 1.0% citrus pectin solution in 10 min at pH 4.5 and 40°C.

Yeast Dried yeast was purchased from Oriental yeast Co., Ltd., Tokyo.

Determination of reducing sugar, total sugar content of easily hydrolysable polysaccharide and starch Reducing sugar was determined by the method of Shaffer-Somogyi.[1] The total sugar content of easily hydrolysable polysaccharide was tentatively expressed as the amount of reducing sugar produced by hydrolysis with 1.0 N HCl at 100°C for 2 h. The starch content was calculated from the reducing sugar produced on incubation overnight at 40°C of mixture of an excess of glucoamylase and a given amount of banana flesh or rind which had been homogenized in a Waring blender with 50 volumes of water and heated at 100°C for 30 min. Sucrose content was estimated from the increase in reducing sugar produced by incubation of banana flesh or rind with invertase preparation from *Candida utilis*,[2] under the same conditions as above. The alcohol fermentation was investigated by weighing carbon dioxide evolved in a modified Meissel fermentation flask.[3]

Green banana fingers were mashed with a domestic electric grater (Matsushita Electronic Co., Ltd.).

Results and Discussion

Carbohydrate content of green banana

The carbohydrate content of green banana analysed by the above methods is shown in Table 1. The starch contents of green banana flesh and rind were estimated to be

Table 1. Analysis of green (immature) banana flesh and rind (%).

	Flesh	Rind	Mean in banana finger
Weight ratio	57.0	43.0	100
Moisture	73.3	91.0	81.0
Reducing sugar	0.16	0.24	0.19
Sucrose	2.1	2.0	2.06
Content of easily Hydrolysable polysaccharide	26.6	6.64	17.9
Starch	20.3	3.64	13.1

20 and 3.6%, respectively. The sucrose contents were 2.1 and 2.0% for banana flesh and rind, respectively. Therefore, the sum of starch and sucrose contents, representing the fermentable substance of green banana fingers, was estimated to be about 17%. The distribution of starch in the banana flesh and rind is shown in Fig. 1, where the starch is stained with iodine.

Alcohol fermentation of green banana fingers On incubation, the mash of green banana fingers rapidly turned dark brown and a tar-like substance appeared in a few hours. But the mash remained firm in texture for several days.

The addition of *Rhizopus* glucoamylase and yeast to the mash (0.1 g and 2.0 g per 100 g banana, respectively) caused alcohol fermentation, but alcohol production reached only half of the maximum level calculated from the starch content.

The simultaneous addition of glucoamylase and pectic enzymes (0.1 g per 100 g banana) to the mash resulted in liquefaction of the mash and further production of alcohol.

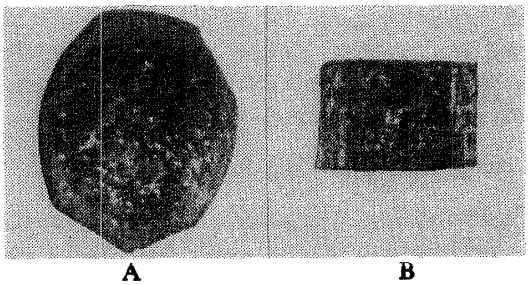

Fig. 1. Starch granules in green banana, stained with iodine.
A, longitudinal section; B, transverse section

But the change in color still occurred and the alcohol fermentation was incomplete even after ten days of incubation at pH 4.5 and at 30°C (75% of total fermentable sugar content). The addition of a great excess of glucoamylase or yeast to the incubation mixture did not improve the fermentation, indicating that the low efficiency of alcohol fermentation was due to the low extent of hydrolysis of starch by glucoamylase (Fig. 2).

To improve the fermentation efficiency, the effect of heating of green banana was examined. The banana was heated in water at various temperatures for 30 min, then mashed and fermented by adding glucoamylase and yeast. As shown in Fig. 3,

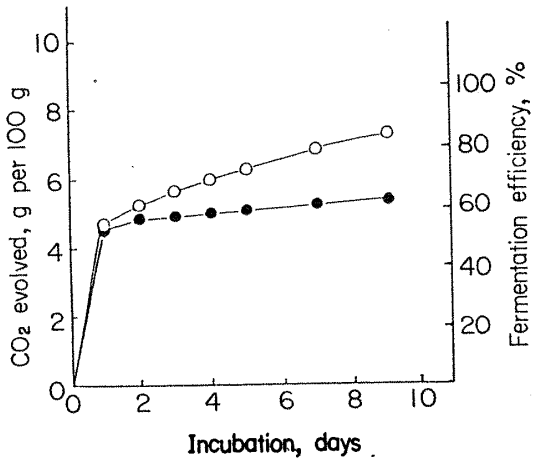

Fig. 2. Effect of pectic enzymes on alcohol fermentation of green banana fingers mashed but unheated. Mashed green banana, 100 g, to which was added 0.1 g glucoamylase and 2 g dry yeast, was incubated with or without 0.1 g pectic enzymes in a modified Meissel fermentation flask.
—○—, with pectic enzymes; —●—, without pectic enzymes

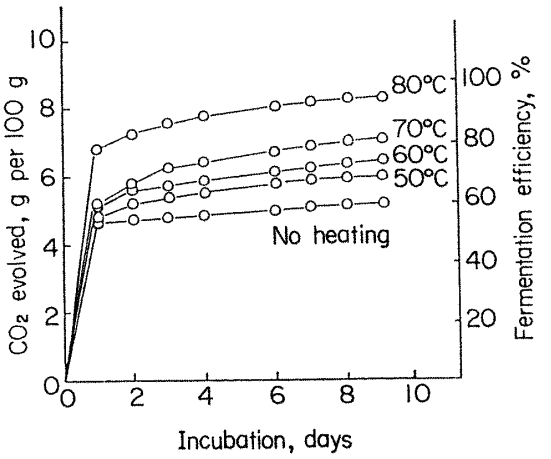

Fig. 3. Effect of heating on alcohol fermentation of mashed green banana fingers.
After heating at the temperature indicated for 30 min, the mashed banana, 100 g was incubated at 30°C with 0.1 g glucoamylase and 2 g dry yeast.

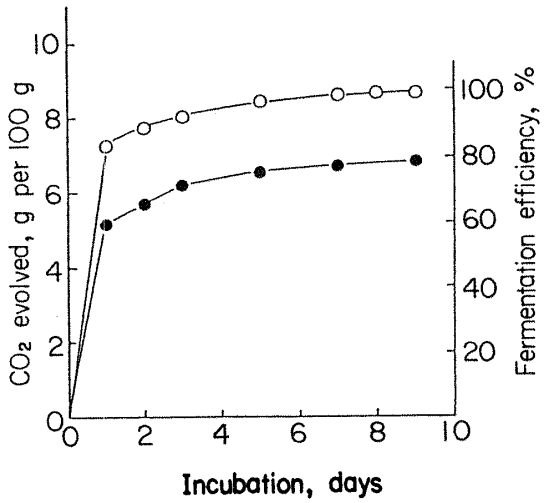

Fig. 4. Effect of pectic enzymes on alcohol fermentation of green banana fingers heated and mashed.
Green banana was heated at 70°C for 30 min and mashed. A 100 g portion of the mash, to which 0.1 g glucoamylase and 2 g yeast had been added was incubated with or without 0.1 g pectic enzymes. —○—, with pectic enzymes; —●—, without pectic enzymes

the banana heated at 80°C resulted in a good alcohol fermentation with an efficiency of 95%. The banana mash prepared after heating at 60°C showed no color change, but was of muddy consistency with a high viscosity even after fermentation.

The addition of pectic enzymes greatly decreased the viscosity of the banana mash. The addition of this enzyme preparation to the mash obtained after heating at 70°C also resulted in complete alcohol fermentation (Fig. 4).

It was found that green banana fingers can be fermented almost completely by the addition of glucoamylase and yeast, provided that the banana is heated at around 80°C. The heating not only prevents the darkening of the mash, it also improves the hydrolysis of starch by glucoamylase. The formation of the tar-like substance from the mashed green banana may be attributed mainly to the action of mono- and diphenol oxidases. In a separate experiment, it was observed that the activity of glucoamylase added to the mashed green banana decreased strikingly. On the other hand, heating at temperatures from 70 to 80°C, for 30 min may be enough to cause considerable gelatinization of the banana starch.

The fermentation mash of the heated green banana with glucoamylase and yeast, however, was hard to handle because of its high viscosity. Thus, the addition of pectic enzymes may be indispensable to fermentation of green banana.

References

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