NOVEL FOOD TECHNOLOGIES TO PROVIDE BETTER QUALITY AND VALUE ADDED FOODS FOR CONSUMERS IN ASIA

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ABSTRACT

Variable food life and increasing competition require food industry to have more technological innovation in food processing. The past decade has seen a tremendous development of food technology such as membrane technology, extrusion cooking, high pressure cooking, ohmic heating (OH) and superheated steam (SHS) cooking which enable the production of new food products with quality, previously unrealized by existing techniques. Research and Development associations were established to assist extrusion cooking and high pressure cooking by private enterprises at a call from the Ministry of Agriculture, Forestry and Fisheries. These R&D associations have stimulated their researches greatly and new foods and feeds have been developed and tested in the market.

For example, a twin screw extruder is catching the attention of food manufacturers because of its high capability in material transportation as compared with a single screw type. The better mixing, kneading, heat exchange and self-cleaning functions of twin screw extruders also provide an incentive to develop this food technology and to iron out the difficulties associated with the single screw type. Recent development of twin screw extruders provides us with new applications to various food processing, especially to better textured protein products and wet processes.

High pressure has tended to receive less attention than heat in the context of food processing. This is obvious because the test apparatuses for food research have been developed relatively late. In addition, the high pressure range hardly has any relevance to food processing. However, recent advances in equipment are expected to make this technology more feasible for food companies, with the understanding that pressure can be applied momentarily and equally applied to any form and composition without leaving any physical damage or any pressure energy after its release. The technique is applying hydrostatic pressure of several hundred MPa on foods for the purpose of sterilization, denaturation of proteins, control of enzyme and chemical reactions, homogeneous defrosting at low temperature and others. High pressure cooking is based on cold isostatic pressing and achieved by applying high pressure to the foods through the surrounding water or liquids.

Ohmic heating (OH) is defined as a process wherein electric current is passed through materials with the primary purpose of heating them, and its capital investment will not be so high. In OH, there is no need to transfer heat through solid-liquid interfaces or inside solid particles once the energy is dissipated directly into the foods. A large number of actual and potential applications exist for OH, including blanching, evaporation, dehydration, fermentation, extraction, sterilization and heating of foods to serving temperature. In addition to the heating promotion, research data strongly suggests that the applied electric field under OH causes electroporation of cell membranes. The cell electroporation is defined as the formation of pores in cell membranes due to the presence of an electric field and as a consequence, the permeability of the membrane is enhanced and material diffusion throughout the membrane is achieved by electro-osmosis. These phenomena are very attractive to improve the rate and efficiency of solid-liquid separation such as the juice preparation and will have high potential to the nonthermal sterilization.

Superheated steam (SHS) is a clear, colorless gas obtained by heating ordinary steam at 100˚C to a higher temperature under normal pressure. The properties of superheated steam approximate those of a perfect gas rather than of a vapor. With its high heat transfer capabilities, it is applied to a wide range of fields including food preparation methods such as roasting, grilling and baking. These phenomena have caught strong interest from the researchers and home appliance makers are competing to sell microwave ovens with SHS.

Meanwhile, what is important to remember is that food safety is an essential public health and trade issue. It is a major concern for consumers, industry and government. As such, the need to address it throughout food supply chains is compelling. The importance of food safety has significantly increased in

recent years following a series of global events associated with incidents of contamination and outbreaks like contamination Escherichia coli O157:H7, dioxin, MCPD, mad cow disease and foot and mouth disease.

Advancement in the field of food science and technology has stimulated the growth of the food industry. However, it has also contributed to the increase in the likelihood of health hazards. Changes in consumers' tastes and preferences that result in the influx of a wide variety of foods greatly impose on the limited resources to ensure food safety. All these have immense impositions on the national governments to ensure food safety both for public health as well as for consumer health protection.

Recent rapid development of fluorescence finger print technique is regarded as nondestructive and quick method and expected to provide us the answer to the above issues.

This presentation will take up a few examples of recent research or industrial achievements in some food technologies in Japan.

KEYWORDS

Extrusion cooking, High pressure cooking, Ohmic heating, Superheated steam, Fluorescence finger print technique

Novel food technologies to provide better quality and value added foods for consumers in Asia

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Better processing with attention to the harmonization and synchronization with existing system

2

- Cooking at high temperature exceeding 100℃
- Superheated Steam (SHS)
- High Pressure Cooking
- Ohmic Heating
- Protein Low Content Rice
- Fluorescence Fingerprint Technique

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Cooking at high temperature exceeding 100℃

4

Family of Soy protein curds

5

Foods and dishes, use or contain the derivatives of soybean

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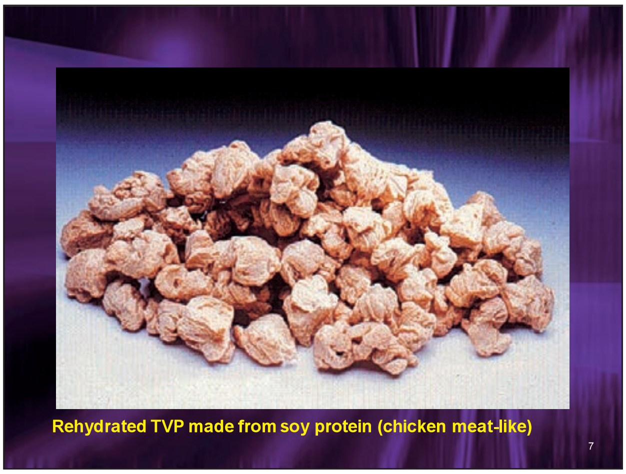
Rehydrated TVP made from soy protein (chicken meat-like)
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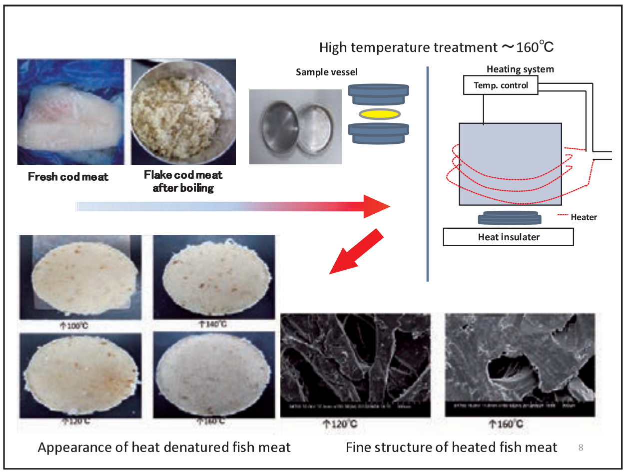
High temperature treatment ～160℃
Sample vessel
Heating system
Temp. control
Fresh cod meat
Flake cod meat after boiling
Heater
Heat insulater
↑100℃
↑140℃
↑120℃
↑160℃
Appearance of heat denatured fish meat
Fine structure of heated fish meat
8

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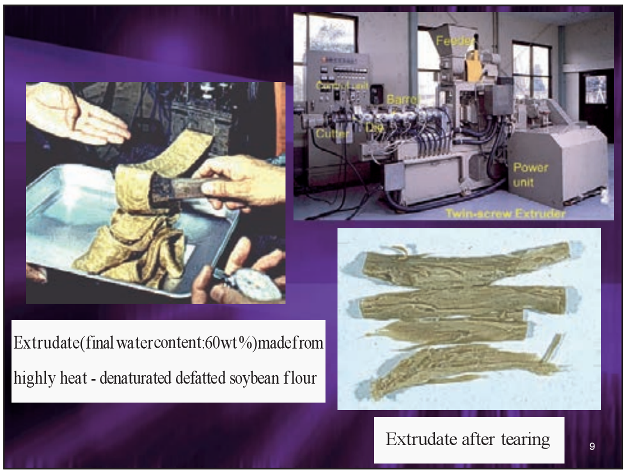
Feeder
Barrel
Cutter
Die
Power unit
Twin-screw Extruder
Extrudate(final watercontent:60wt%)madefrom highly heat - denaturated defatted soybean flour
Extrudate after tearing
9

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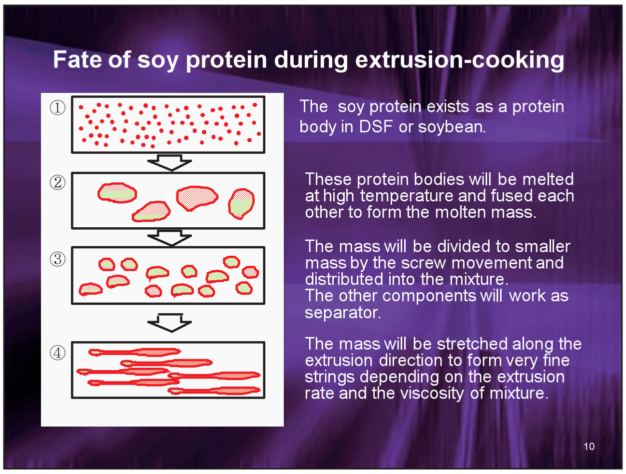
Fate of soy protein during extrusion-cooking
①
②
③
④
The soy protein exists as a protein body in DSF or soybean.
These protein bodies will be melted at high temperature and fused each other to form the molten mass.
The mass will be divided to smaller mass by the screw movement and distributed into the mixture.
The other components will work as separator.
The mass will be stretched along the extrusion direction to form very fine strings depending on the extrusion rate and the viscosity of mixture.
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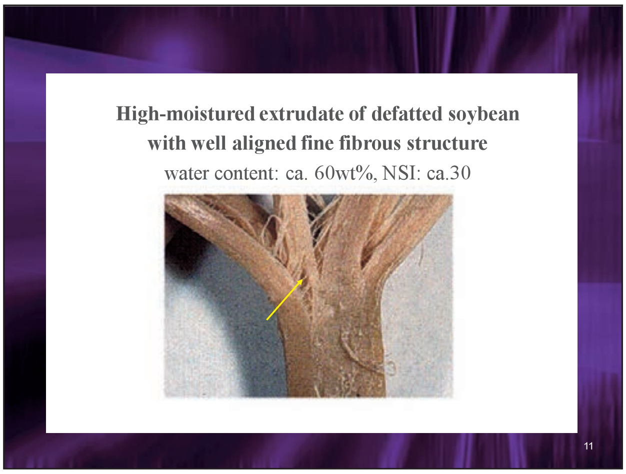
High-moistured extrudate of defatted soybean with well aligned fine fibrous structure
water content: ca. 60wt%, NSI: ca.30
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シーグレイス
Scallop Adductor analog
Crab meat analog made by Wet Extrusion
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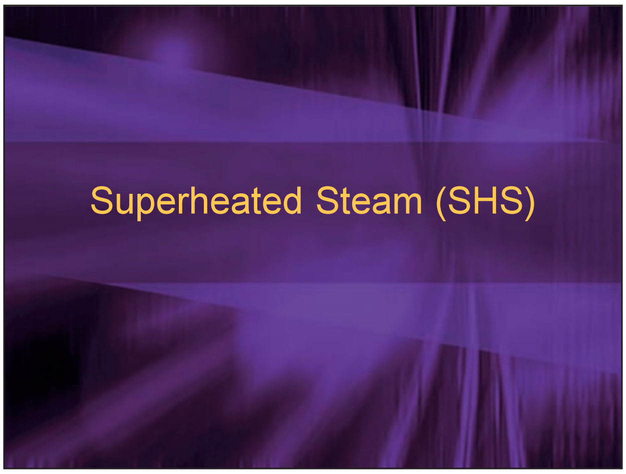

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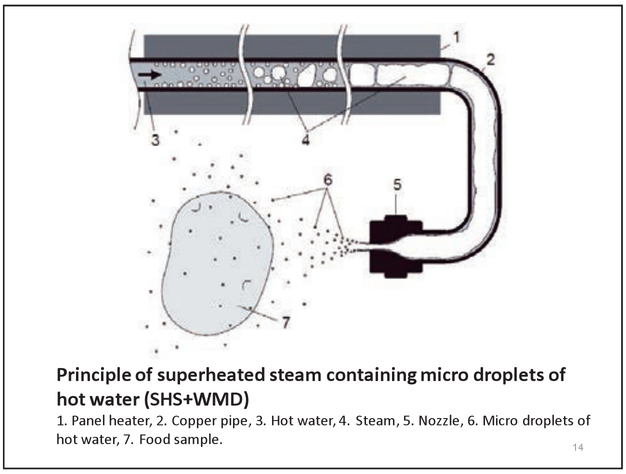

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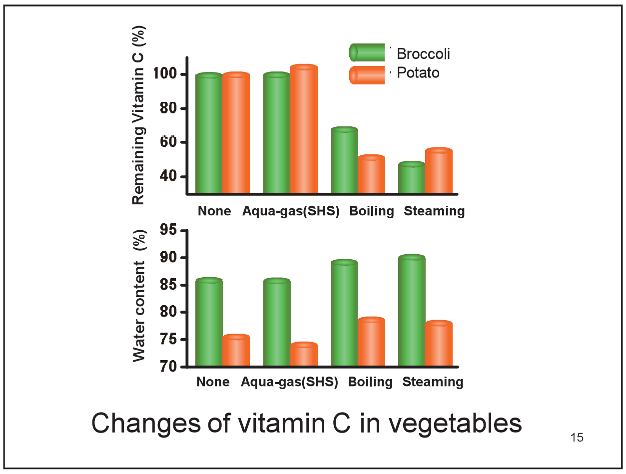

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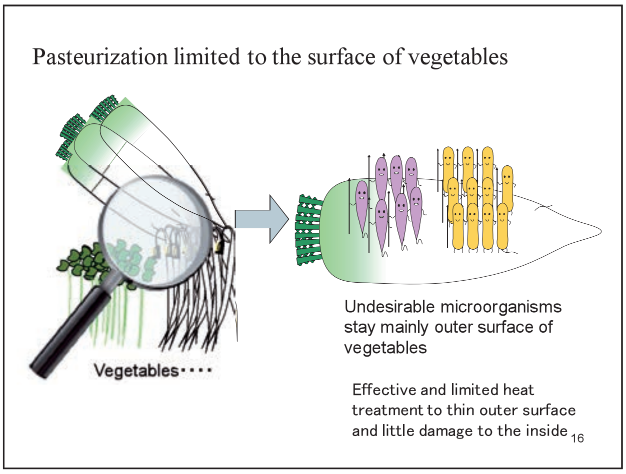

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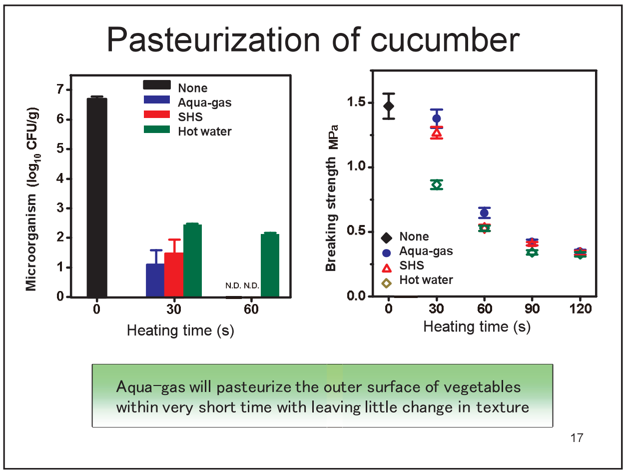

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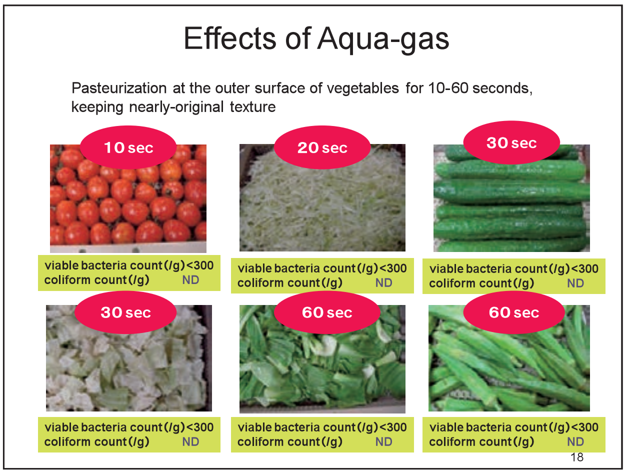

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Practical machine and its applications

For kitchen use
（Taiyo Seisakusho Co., Ltd.）

Potato salad processed by Aqua-gas
（Rose Corporation Co., Ltd.）

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High Pressure Cooking

(In fluid)

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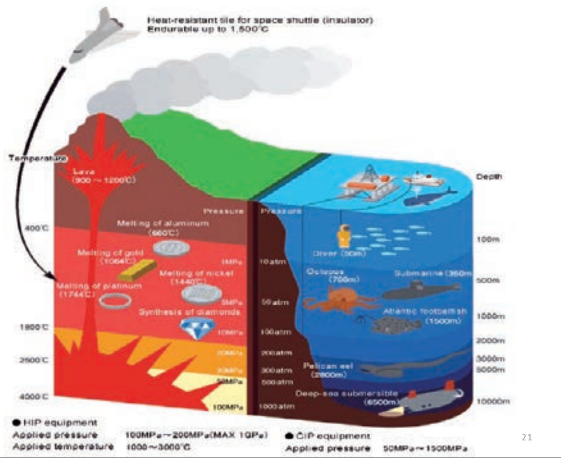

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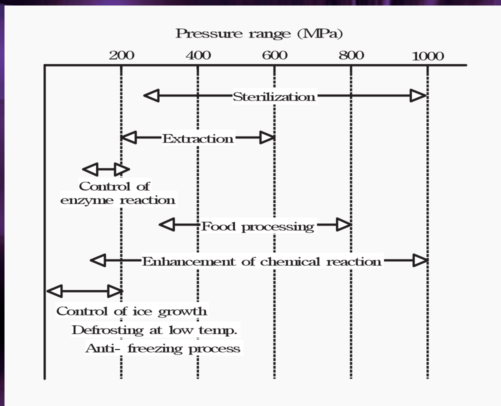
High Pressure Cooking



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The world's first jam
prepared by high pressure
(available for sale to this day;
Meidi-Ya Co., Ltd.)

Ready-to-eat brown rice
- more soft and elastic texture
- 100% Niigata brown rice and no additive
- better digestibility

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Various pressure-foods offered commercially in other countries
(for example, Avocado, Oyster, Fruit juice, Meat)

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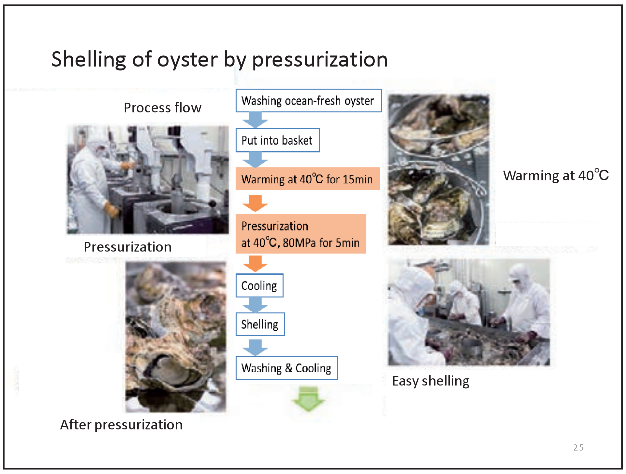

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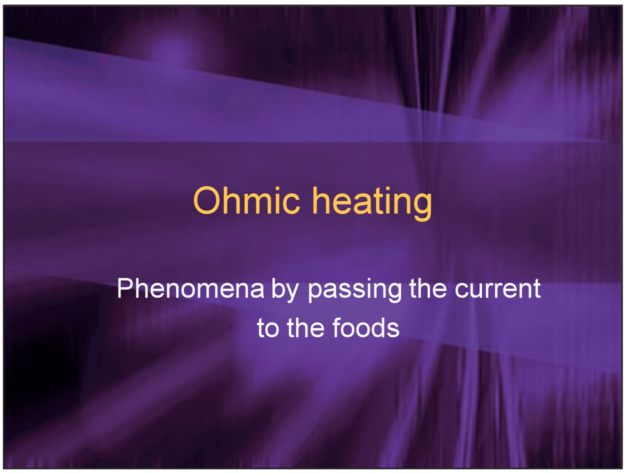

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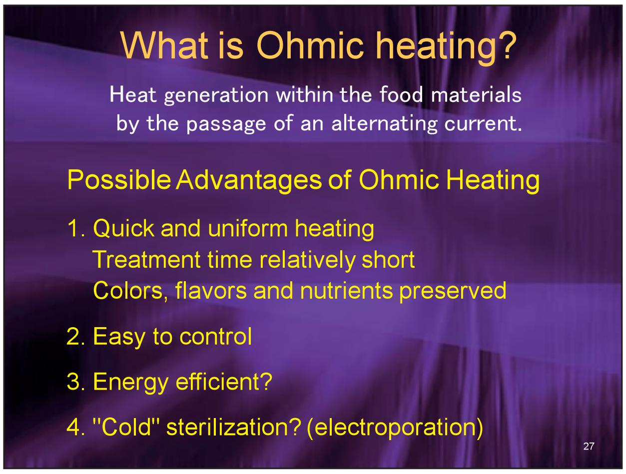

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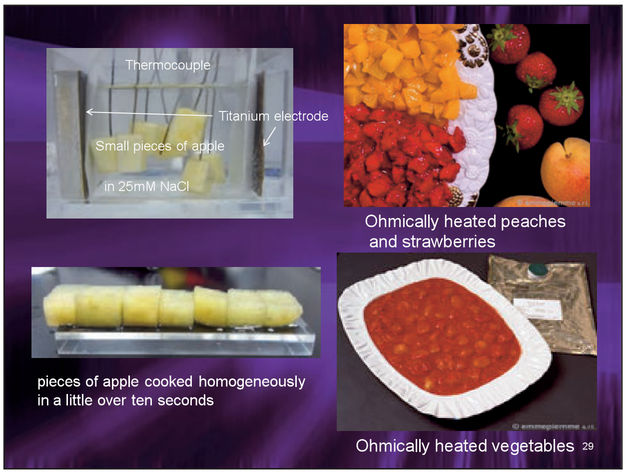

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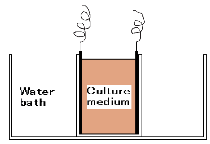
Fermentation with Ohmic heating



- Microorganism: Sake yeast K-7
- Culture medium: YM-10
- Conditions of Ohmic heating:
  Frequency: 60Hz or 3kHz
  Applied voltage:3.2V/cm

●The temperature of culture medium is maintained at 30℃ by Ohmic heating.
●The electric consumption is controlled by the difference in temperature between water bath and culture medium.

Methods

- **Cell count**
  Cell density was determined with a hemacytometer
- **Ethanol production**
  Determined by Head-Space GC
- **Glucose concentration**
  Determined with Glucose C2-Test Kit (Wako Pure Chemical Industries, Ltd)

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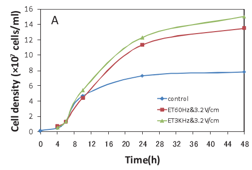
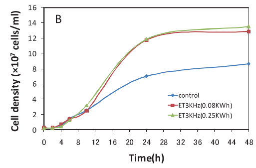
Influence of Ohmic heating on growth of Sake yeast



(A) Influence of electric frequency
Culture medium temperature:30℃
Water bath temperature:28℃



(B) Influence of electricity consumption
Culture medium temperature:30℃
Water bath temperature:28℃ (ET3kHz(0.08kWh)
Water bath temperature:20℃ (ET3kHz(0.25kWh)

●The growth rate was increased by Ohmic heating and the final cell density was larger than that of the controlled. And the promotion effect was higher at 3 KHz than that of at 60 Hz.

●The influence of electricity consumption on growth of Sake yeast was not obvious.

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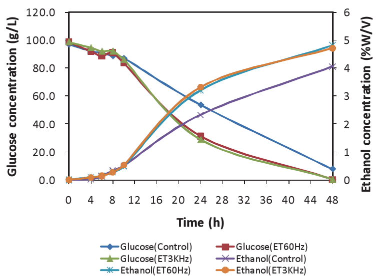
Influence of Ohmic heating on glucose consumption and ethanol production



●The rate of glucose consumption and ethanol production increased during the Ohmic heating treatment

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Protein Low Content (PLC) Rice

~Improving "the Quality of Life"
of
Chronic Kidney Disease patients~

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Production Flow

1. Material → 2. Wash → 3. Enzymatic treatment →

Rice grain (*Oryza sativa* L. *Japonica*)

Put the material in a reactor tank. And wash the rice in water.

1) Fill the tank with organic acid solution.
2) Dissolve a protease(s) in the solution and incubate overnight.

4. Rinse → 5. Feeding → 6. Cooking (Aseptic room) →

1) Discard the reaction solution.
2) Rinse gently with cold water.

Feed the treated-rice in a plastic pack with filling machine.

Cooking by steaming.

7. Sealing (Aseptic room) → 8. Cooling → 9. Boxing / Shipping

1) Substitution of air by nitrogen.
2) Cover with an oxygen scavenger attached plastic film.

Cooling in a refrigerator.

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"PLC Rice"

Products				
Protein content* (in 100 g of product)	0.83 g	0.5 g	0.25 g	0.125 g
Net	160 g	180 g	180 g	180 g

Products			(Uonuma Koshihikari)	(Dried type)
Protein content* (in 100 g of product)	0.1 g	0.1 g	0.1 g	0.24 g
Net	180 g	150 g	180 g	1 kg

* 100 g of cooked rice contains **2.5 g** of protein.

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Nutrient composition of “PLC Rice”

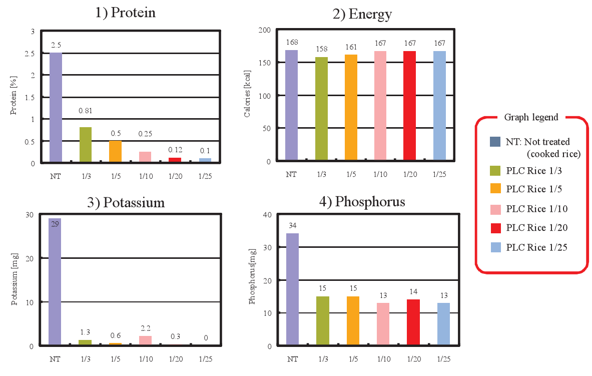

Fig. Nutrient compositions (per 100 grams)

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Summary

1) Development of Technique and Products

It can cut down some of the nutrient amount in rice grain (see below).

- Protein (amount of optional; 68-98%)
- Potassium (above 90%)
- Phosphorus (approximately 60%)

2) Expected Effects

a) “PLC Rice” is helpful for Chronic Kidney Disease (CKD) patients who require restrictions of “protein,” “K” and “P” intake.

b) It would be expected that “PLC Rice” provides CKD patients the beneficial effects of “delaying onset of dialysis by slowing aggravation of CKD stage” and “reducing the cost of dialysis.”

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Quality Evaluation

Non-destructive Analysis

With Dr. J. Sugiyama’s agreement (NFRI)

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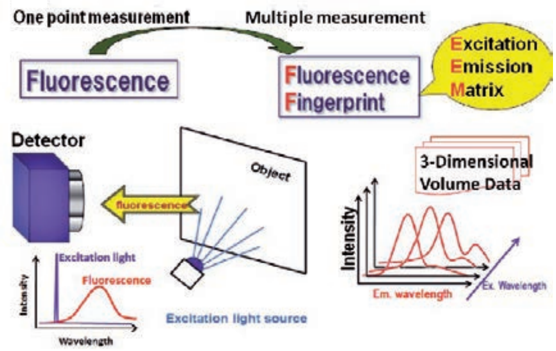

Fluorescence fingerprint

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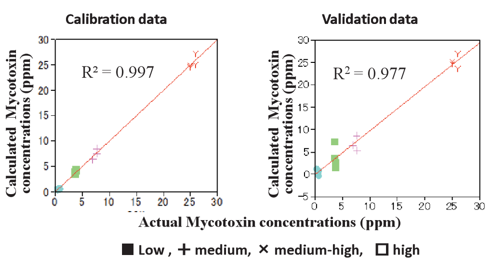
Prediction of DON (deoxynivarenol) Concentration in Contaminated Wheat



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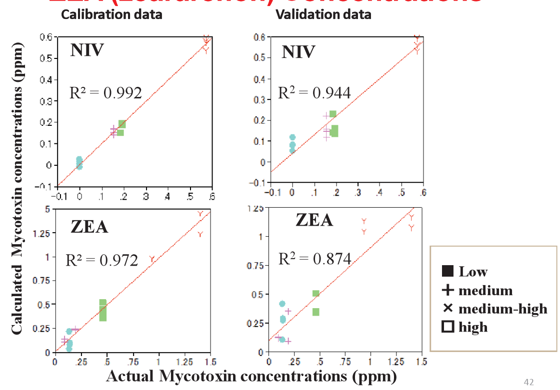
Prediction of NIV (nivarenol) and ZEA (zeararenon) Concentrations



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Conclusion

Fluorescence fingerprint technique was applied to detect food hazards quantitatively.

This method is nondestructive and quick measurement and shows high potential to measure ppm or ppb order for mycotoxin and APC (aerobic plate count) between 102 and 108 CFU/cm^2.

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Acknowledgements

I would like to thank my research partner, Dr. Honghai Hu, alumnus of China Agricultural University for his invaluable assistance on the research accomplishment.

Some part of this work was a part of City Area Program supported by the Ministry of Education, Culture, Sports Science and Technology, Japan.

Thanks for your attention!

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Chair Matsunaga: The last speaker is Dr. Akinori Noguchi. He holds a doctorate degree in science from Tokyo Institute of Technology. He is currently a professor of Ishikawa Prefectural University, Japan. He is also a board member of Tottori Institute of Industrial Technology. His expertise is in the area of food science and technology. He has won both domestic and international awards in food science. His presentation today is “Novel Food Technologies to Provide Better Quality and Value-added Foods for Consumers in Asia.” Prof. Noguchi, please.

Dr. Akinori Noguchi: Thank you, Chairman, for your kind introduction, and also thanks, JIRCAS, for their kind invitation. Well, I think the sustainable development of production will require harmonization and synchronization with other fields. And I would like to focus my attention on processing, and I will touch a little bit on nutrition and quality assessment.

Food processing will contribute to the production side by adding value, improving income, providing a rich and varied diet, and creating employment, especially in local Asia. I will pick up some food technology which I hope will serve as useful reference.

Today I will introduce these technologies in turn, from high-temperature cooking to the fluorescent fingerprint technique.

First, the high-temperature cooking above 100 degrees Celsius. These products are the traditional and familiar protein foods found in the Japanese market. And they are also familiar in the market and, including the former case, they depend their processing on the protein function such as high solubility and gel formation. Unfortunately, these functions are so much sensitive to temperature and will be lost more than 80 or 90 degree Celsius within a very short time.

This product is called textured vegetable protein, in short TVP, and produced mainly from poor soluble soy protein. After rehydration, this TVP resembles boiled chicken meat. How can we transform such a protein, a poor soluble protein, to this product?

This figure shows you the change of fresh cod meat after high temperature treatment. The cod meat is boiled and changed to flakes as shown in this slide. And then the flake is added a small amount of water and transferred into a vessel and heated to various temperatures in a short time. After the treatment, the flakes are found to change to thin snack-like at all examined temperatures, and a scanning electron microscope reveals that the muscle fiber is like thermoplastic and seems to be fused some other at cross-over point. These results suggest that the fish protein will have thermoplastic property and can be transformed to various shapes even after heat denaturation.

This photo shows the elastic meat analog from highly-heat denaturated soybeans produced by twin-screw extruders. The product can be torn easily along the extrusion direction and shows elastic toughness its right angle.

This figure shows you the possible change of the soy protein during cooking. The soy protein will be molten before the outlet of the machine and stretched to thin fiber and then could fix its structures.

This figure shows you the very fine and well-aligned protein fiber in the product. It resembles cuttlefish from soy proteins.

This process can be applied to other proteins such as fish meat, and some of the products are already in testing in the Japanese market.

The second topic is on super-heated steam, in short, SHS. This SHS has been studied due to its various advantages. For instance, high-temperature, high-heat transfer by condensation and gas radiation, and these phenomena make it possible to have high-temperature short-time cooking in a relatively low-oxygen environment. And this technology has been studied for blanching, drying, and pasteurization especially.

This figure is the schematic drawing of an SHS generator. The water is heated and this water is boiled inside a copper pipe under relatively high pressure. And then the boiling water and steam are subsequently sprayed through the nozzles. The hot water is atomized with the nozzles and is suspended as microdroplets of hot water in SHS.

And this figure shows you the beneficial effects of this SHS on vegetables. SHS retains the original level of vitamin C and also the water content in the examined vegetables.

There can be high potential to kill undesirable microorganisms on vegetables, keeping their original texture.

These results clearly indicate SHS will provide you better processed vegetables and also elongation of their shelf life.

This figure shows the effectiveness of SHS to supply clean and more safe vegetables to consumers. And the machines are now available in the market and processed foods are now also found in the Japanese market.

Let me move to the third topic, that is high-pressure cooking. This figure shows you high-pressure conditions in nature. For example, in the deep sea we will have very high pressure at the bottom of the sea, and also in the center of the earth, maybe we have incredible high pressure, but this high pressure now can be produced by our machines.

The pressure has tended to receive less attention than heat in the context of food processing; however, recent advances in equipment are expected to make this technology more feasible for food companies with the understanding that the pressure can be applied momentarily and equally applied to any form and composition without leaving any physical damage or pressure energy after it is released.

The long study revealed its various effects as shown in these figures. This figure shows you the actual product. The left side is the world’s first jam processed by high pressure and available in Tokyo today, and the left side shows you the ready-to-eat brown rice which shows you a very soft and elastic texture and better digestibility.

We can find a similar product processed by high pressure even in other countries, as shown in this figure. For example, from avocados, oysters, fruits, and meat.

This is a very interesting application of high pressure. As you might know, the shelling of oysters is very hard and needs many people and time for processing. However, pressurization will completely change this troublesome process. For example, the fresh oysters will be washed and put into the basket and then warmed to 40 degrees Celsius and then pressurization. Only five minutes. So then the oyster opens its shell and we can take out the fresh meat by hand very easily.

So now let me move to the next topic, Ohmic heating.

When a food product or food material contains sufficient water and electrolytes to pass an electric current, that is alternating current, then we can expect Ohmic heating. This Ohmic heating will generate heat homogeneously inside of the food and this method enables a solid phase or solid material or even a viscous liquid to heat up very quickly like a thin liquid.

One of the industrial achievements of this technology in Japan is the production of bread crumbs. Its annual production has now reached to almost 60 percent.

This figure shows the actual application of this Ohmic heating at the laboratory scale. The left side uses a fine apple treatment by Ohmic heating. Small cubes of apples are put into the small solution and we apply voltage, then within a very short time, just a little over ten seconds, the small pieces of apple are cooked, keeping their shape. And very quick cooking.

And also, a similar product can be found in the Japanese market and also in another country, as shown on the left side of this figure.

Let me introduce how this Ohmic heating is also applicable to fermentation. The culture medium for fermentation can be adjusted its temperature quickly by Ohmic heating and maintained without any mixing. And in this study the cell density, ethanol production, and glucose concentration in media were measured.

As you see here, during the Ohmic heating, the growth rate of the yeast is increased and the final cell numbers are larger than that of the control. And also, as shown in these figures, the rate of the glucose consumption, this one, this is the control one, but when we apply the Ohmic heating, as you see here, we will have the increment of the glucose consumption and we will expect the better ethanol production by applying Ohmic heating.

Time is limited so I will rush to the next topic, that is protein low-content rice. A company in the northern part of Japan just recently started to produce the protein low-content rice. This figure shows you the production flow or process flow. After washing the rice, they treat the rice with enzymes, and after protein digestion they are cooking it under relatively high pressure.

This is a figure or actual photographs of their product. As you will find, almost all of them will have a very low protein content. The lowest one is one-twentieth. And this figure shows the composition of these products.

In the case of protein, it’s so much reduced and the total calories are maintained the same as the original one almost, but potassium is also so much reduced, and phosphorus in the product almost changed to half.

So this company summarized as an advantage for this product the low-protein content also has very low potassium and a big reduction of phosphorus, and the expected effect, they call this rice PLC rice. Protein Low-Content Rice is helpful for chronic kidney disease patients who require a restriction of protein, phosphorus, potassium, and phosphorus intake. And it is expected that this product provided to a patient has a beneficial effect of delaying the onset of dialysis and also reducing the cost of dialysis. I think this kind of product is so beneficial or helpful in neighbor countries such as China.

The last one is a quality evaluation, that is non-destructive analysis. The recent development of sensor and computer technology makes a lot of changes in our surroundings. The utilization of these developments could introduce innovation even in our food industries.

Fluorescence is a well-known technique is analytical chemistry. This figure shows you the principle of the data collection of a fluorescence fingerprint. The scanning of excitation wavelength produces a lot of fluorescence spectrum. And there are three-dimensional volume data consisting of excitation wavelength, emission wavelength, and fluorescence intensity arcs.

This figure shows you the prediction of very harmful chemicals, in short, DON, concentration in contaminated wheat flour. Both calibration and validation data show a significant correlation between actual value and predicted values.

This is the result of other harmful chemicals, mycotoxin NIV and ZEA. They have also good correlation. Especially the remarkable point is sensitivity to predict NIV. The order is almost ppb levels and conventional chemical analysis cannot detect them at these levels.

So as a conclusion I must say that this method is classified as a non-destructive method and very quick measurement and shows high potential to measure the ppm or ppb order for mycotoxin. And even if we apply this technology to living cells on food material, such as fresh beef meat, we can detect them at the level of number 100 or at just less than 100, so I think this kind of non-destructive method will be a very powerful tool to serve fresh and clean food to consumers. And their capital investment is very low and the analytical necessary time will be sometimes ten minutes.

So maybe I can contribute to the Chairman to shorten my presentation time because we are a little bit behind schedule, so I conclude my presentation by saying thank you to my research partner, Dr. Hu, from China Agricultural University for his very nice assistance, and also I express my thanks for the financial support from the Ministry of Education, Culture, Sports, Science and Technology. Thank you for your attention.

Chair Matsunaga: Thank you very much, Dr. Noguchi, for your fantastic presentation. Time is almost running out so I would like to move to general discussion of this session.