Discover KAGAWA through English and Science

A Kagawa University Student Project

Discover Kagawa

through English and Science

Discover Kagawa

through English and Science

A Kagawa University Student Development Project

Keisuke Hashii
Tomomi Hasegawa
Nao Idegami
Mai Kadota
Moei Taniguchi
Taku Toyama
Daichi Toyonaga

Kagawa University Student Development Project Press

Science is not only a disciple of reason, but, also, one of romance and passion.

Stephen Hawking, 2010

The limits of my language mean the limits of my world.

Ludwig Wittgenstein, 1953

Education is the most powerful weapon we can use to change the world…

Nelson Mandela, 2003

©2015 by the authors. All rights reserved. All other rights remain with the authors. The authors grant permissions to high schools and junior high schools in Kagawa Prefecture to copy this material for educational proposes, either for class use or individual study.

To cite this book for a school project:

Bibliographic reference:

Hashii, K., Hasegawa, T., Idegami, N., Kadota, M., Taniguchi, M., Toyama, T. & Toyonaga, D. (2015). *Discover Kagawa through English and science*. Miki, Kagawa: Kagawa University Student Development Project Press.

In text citation

Hashii et al. (2015) stated that…
(Hashii et al., 2015)

Photo Credits

National Aeronautics and Space Administration (p. 1), Kazuya Akimitsu, Peter Lutes, Kenji Morimoto, Goro Takada, Akihide Yoshihara and project team members: Mai Kadota, Moei Taniguchi, and Daichi Toyonaga. Other photos are public domain photos that have had all rights waived (pp. 3, 4, 5, 7, 8, 16, 18, 27).

Kagawa University Student Development Project Press
2393 Ikenobe, Miki-cho, Kagawa Prefecture, Japan 761-0795

Printed in Japan

Table of Contents

Preface

If a visitor asked you, "What is Kagawa?", would you be able to answer them?

This book was written for high school students and offers one answer to this question. In this book, we highlight some of the key features of Kagawa Prefecture from a scientific and a socio-historical perspective. Water, *Udon* and Rare Sugar have become closely linked to Kagawa Prefecture, so we have given an overview of these key parts of Kagawa Prefecture's identity.

We hope that by writing this book in English, students that are focused on science may enjoy using English as a tool to get scientific information. At the same time, we hope that students that are more interested in the English language may gain an interest in science through their pursuit of studying English.

We hope that you enjoy discovering science and the English language in this book and that it helps you become more interested in science and the English language.

Acknowledgements

We would like to thank the President of Kagawa University, Professor Seigo Nagao for his support of this project through the Kagawa University Student Development Project. We would like also like to express our appreciation to the faculty members of the Faculty of Agriculture of Kagawa University for their guidance and support: Professor Kazuya Akimitsu, Associate Professor Goro Takada, Associate Professor Kenji Morimoto and Assistant Professor Akihide Yoshihara and Visiting Instructor William Seil. Finally, we would like to give special thanks to Associate Professor Peter Lutes for editing this book and for being the project advisor.

Water

Introduction

The first man in space, Yuri Gagarin, said the Earth is blue. Our planet is covered by water. Water is a blessing, but sometimes it can cause disasters. People have struggled with droughts and floods since ancient times. Each point in history has its own story about water. For example, in ancient Egypt, people used the Nile River flood to cultivate grain. The Nile River brought fertile soil from the upper stream and revitalized the fields. The ancient Romans built many aqueducts, totaling over 350 kilometers in length. It is estimated that in 300 B.C. the aqueducts, built by the Romans, supplied the City of Rome one billion L of water per day. This is enough water to fill 250 million bathtubs!

A Roman aqueduct

Today people make gigantic dams, canals, ponds, water reservoirs, and so on to control and to better use this precious natural resource. Of course, Kagawa Prefecture has a long history of water management. These days, most people do not worry so much about water because high technology has allowed us to control and maintain the water supply. However, we have to be mindful of water in Kagawa because some big challenges exist.

A large dam

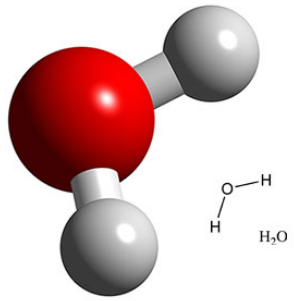
Perhaps the biggest challenge is the shortage of water. The unique geographical features in Kagawa contribute to water problems. However, the ancient residents of Kagawa were able to adjust to the environment and created a unique culture. So in this chapter, we will focus on water. We will examine the chemical features of water, secrets of seawater, and the history of Kagawa, including geographical features, culture, the latest research, and the challenges facing the people of Kagawa. There are many problems related to water in Kagawa. Let's begin our journey to discover the water.

The secret of life on Earth

In our giant universe, the key reason that there is life on earth is the existence of water. The National Aeronautics and Space Administration (NASA) focuses its search for life on Mars by looking for evidence that water existed on Mars. If water existed on Mars, then it is very likely that life also existed on Mars. Water is the key requirement for life.

About 70% of the surface of the earth is covered by water. Our bodies are composed of between 60 to 70% water; so it goes without saying that water is the essential substance for life. In this chapter we will introduce two important features of water for life: a strong polarity, and a high specific heat capacity.

Water is a simple molecule made up of one oxygen atom and two hydrogen atoms, but is essential to life. One of the most important features of water is that many substances can be dissolved in water, such as sugar, salt, alcohol, etc. This feature is critical for life because water works as a solvent in our bodies.



Water molecule

Aleksandr Ivanovich Oparin, a famous Russian biologist, hypothesized that life was born from special primordial soup, which was composed of water and many other dissolved substances.

Water can dissolve many substances because of its polarity, which helps substances dissolve or melt in water. Polarity refers to the unequal sharing of electrons within the water molecule for the bonding between the one oxygen atom and two hydrogen atoms. Every atom has an ability to pull electrons. The value that indicates this pulling ability is called electronegativity. Electrons are attracted to atoms that have stronger electronegativity. Fluorine atoms have the strongest electronegativity.

We can compare polarity to a tug of war. Since oxygen is a much bigger atom than hydrogen, we can imagine that oxygen is like a Sumo wrestler. Meanwhile, hydrogen is a small atom, so it is like an elementary student. In a water molecule, there are two elementary students and one sumo wrestler. The sumo wrestler is overwhelmingly stronger than the two elementary students. The sumo wrestler easily pulls the elementary students. The rope that is used to bind and pull is formed by the electrons.

So, in a water molecule, electrons are attracted to the oxygen atom. The oxygen atom has a negative charge. In a water molecule, oxygen has a negative charge and hydrogen has a positive charge. These charges are similar to the polarity of a magnet, which allows it to dissolve other substances.

Another very important characteristic of water is its heat capacity. Heat capacity is the measurable physical quantity of heat energy required to change the temperature of an object by a certain amount. Water has an incredibly high heat capacity. This means water needs a lot of energy to be warmed or cooled. This feature helps maintain the climate of earth and helps to stabilize the temperature in our bodies, at about 36˚C.

Water in the world

The Earth contains a great amount of water, about, 1.4×10^{15} L. This is about 90 billion times the amount of water in Mannou Reservoir, the biggest reservoir in Japan. Seawater accounts for about 97% of the water found on the earth. Seawater does not consist only of water, but many other substances such as metals. In one liter of seawater, there are 23 g of salt NaCl, 4.98 g KCl, 3.98 g $MgCl_2$, 0.66 g KCl, and other substances.

Amazingly, seawater even contains gold. However, there is not enough gold to make you rich, only about 1 g per 1×10^{12} L of seawater. This means you would get only 1 g even if you were to gather 660 thousand times the amount of seawater of 25 m swimming pools.

The ancient earth

We have to look at the history of the earth to understand why these substances are found in seawater. The earth was born 4.6 billion years ago, as a fiery hot gas giant. As the earth cooled, water vapor changed into liquid water and dissolved chlorine. This was the beginning of the creation of seas, about 4.3 billion years ago.

At first, the seas were very acidic because the water contained hydrochloric acid. After that, the acidic seas dissolved other substances, such as sodium and potassium found in the rocks. Our seawater today can dissolve substances in the same way and rate as ancient seawater. It is because of the water balance and salt balance.

First, let's think about water balance. Water exists as a solid, liquid and vapor. About 5.0×10^{17} L of water vapor changes into liquid water every year. Meanwhile, the same amount of liquid water changes into water vapor. This means that 42.5×10^{16} L of water evaporates from the sea every year and rains bringing 38.5×10^{16} L into sea with rivers bringing 4.0×10^{16} L to the sea. Of course there are some variations from year to year, but essentially it is relatively stable. This is called water balance.

The sea is supplied with salt. The main source of this salt is rock. Many substances have been dissolved into the sea since the seas first formed. In addition to rock, there are other sources of salt, such as yellow dust. Yellow dust is the famous dust from the Yellow River region, which originates in the Taklamakan Desert and the Gobi Desert in China. It is transported to other parts of China as well as Japan and Korea by strong winds. Of course, some of the yellow dust falls into the sea and is a source of salt.

Underwater volcanoes also contribute to supply of salt. There are many changes to the sea but in spite of these changes, the level of salt is relatively consistent.
Seawater is always moving. As you can see when you look at the sea, the surface always has waves, which are caused by wind, the earth's rotational spin, and the gravitational pull of the moon. Seawater on the surface layer is moved by the wind. When the wind blows in a certain direction, the surface of the sea is dragged by the wind and starts to flow. "Oyashio" and "Kuroshio," which flow around Japan, are these kinds of surface currents.

The sea

Water in deep areas moves more differently than surface water. Deep water moves slowly, at one centimeter per second. It takes about 1000 years for water to circulate around the world. The factors that influence this flow are different because deep water flows slowly. The movement of deep water depends on the density of salt.

Geographical features

Kagawa has unique geographical features. It stands on granite, a kind of hard rock. Granite is formed from magma. There is a series of mountains, in the south, and a small plain called “Sanuki Heiya”. The geographical features in Kagawa contribute to the shortage of water. The annual precipitation in Kagawa is 1082 mm which is the least amount of rain compared to the annual precipitation of other prefectures in Japan because mountains surround Kagawa. Since there are small plains and steep mountains, the rivers in Kagawa are short and small. Therefore, people in Kagawa have faced water problems since ancient times.

Ponds and Dams in Kagawa

In Kagawa there are about 14,000 ponds. Water is pooled or collected, sorted, and diverted for many reasons, such as disaster prevention, natural ecosystem preservation, the designation of recreational waterside spaces, and so on. Kagawa is famous for having the most water reservoirs in Japan. The oldest water reservoir is Mannou Reservoir. Mannou Reservoir is a man-made pond that was built between 701 through 704 on the orders of the governor of Kagawa, Michimori Ason. But in 818, it collapsed because of flooding. The Imperial Court tried to start reconstruction, but because of technical problems and labor shortages, the reconstruction project never started.

Nagara reservoir

In 821, Kukai was chosen to restructure Mannou Pond. Kukai’s return to his hometown attracted many people, solving the labor shortage problem. He used the civil engineering skills that he had learned in China to complete the reconstruction in less than three months.

In the following centuries, Mannou Reservoir was repeatedly damaged and repaired. However, in 1184, it collapsed after heavy flooding. This was during a time of political instability, the Warring States period, so it was not repaired. In 1631, it was again repaired. In 1854, an earthquake destroyed it, and again in 1870, it was completely rebuilt. In the years after World War II, it was expanded; the volume of water reserve was tripled to secure and better manage the water supply.

With the progress of the urbanization, demands for water increased, so the number of dams and water reservoirs also increased. Today, this system of dams and reservoirs supplies city water and industrial water, and helps to prevent flooding. There are approximately 14,000 dams and water reservoirs in Kagawa.

Sameura Dam is one of the most important dams in Shikoku. It is the chief water reservoir for Kagawa Prefecture. It can store 31.6×10^{13} L of water. Constructed in 1975, it is linked to the Yoshino River. In 2005, a prolonged drought resulted in a severe water shortage literally emptying the Sameura Dam, indicating that Kagawa Prefecture may need to develop more water reservoirs.

Sameura Dam has another important role in water management, to prevent flooding. In 2009, torrential rains struck Shikoku, but the water was collected and stored in Sameura Reservoir, preventing flooding.

There are also challenges in using water reservoirs. Nagara Reservoir, like many reservoirs in Kagawa, faces a water pollution problem. Normally, there is some phosphorus in the water, but polluted reservoirs have too much phosphorus. Phosphorus has a strong influence on the water and environment, such as reducing oxygen at the bottom of the reservoir. It is because it was used to decompose organic matter. So eventually, oxygen will be completely depleted. Water pollution is an import issue for reservoirs.

Reservoirs in Kagawa Prefecture tend to suffer from eutrophication. In a healthy reservoir, nitrogen and phosphorus are quite low. Nitrogen and phosphorus are

essential substances for life such as harmful microorganism. If the levels are low, microorganisms are prevented from growing. Unfortunately, some human activities produce nitrogen and phosphorus, which end up in the rivers and seas, resulting in an increase in microorganisms.

Nagara reservoir is the most eutrophic reservoir in Japan. Nagara reservoir is relatively rich in nitrogen and phosphorus, which results in algal blooms from early summer to late autumn. Algal blooms are floating mats that consist of blue-green algae. Blue-green algae have a bad smell and destroy the scenery. Also, it can affect the quality of drinking water.

Since zooplankton do not eat blue-green algal, the dead blue-green algal are accumulated at the bottom. Bacteria use great amount of oxygen in the water when they decompose dead blue-green algal into CO_2 and H_2O. In the summer, the surface of water is heated by sunlight. Generally, warm substances rise to the surface and the cool ones sink to the bottom. But in a pond, the top water is warm and the bottom water is cool. However, this difference of temperature cannot cause the circulation of water. Circulation of water plays a role of supplying oxygen. Without water circulation, the oxygen supplies stop. As a result of the different temperatures, water at the bottom lacks oxygen. Fish can't live in the water that has less than 4 mg/L of dissolved oxygen.

In addition, water that lacks dissolved oxygen makes CH_4 and NO_2 facilitate the green house effect. CH_4 emission can be as much as one sixth of the CH_4 emission of a garbage disposal plant.

Udon


月見うどん
肉うどん
しっぽくうどん
天ぷらうどん
きつねうどん
かけうどん
カレーうどん
ぶっかけうどん
釜あげうどん
ざるうどん

Introduction

In Kagawa, eating Udon is part of nearly everyone's daily routine, while in the rest of Japan, it continues to become a popular and iconic dish. Although Udon is a delicious and inexpensive food, it has great influence on human health. In Kagawa, there is a word – "Sanuki-Sanpaku." When you hear the word, you know it means, "cotton, sugar and salt". However, people from other prefectures may think that the answer is "salt, sugar and Udon." Udon has had a large impact on Japanese people nationwide, even though they misunderstand Sanuki-Sanpaku. Nevertheless, this mistake is one you will not make because you live in Kagawa. People who live in Kagawa have to share the correct information, not only in Japan but also abroad.

Udon has an interesting history. Kagawa has a serious problem with water supply, often suffering from water shortages, and has many mountains, which means that farming land is limited. For these reasons, people in Kagawa made and popularized Udon. Udon is very popular because it is inexpensive, widely availably and easy to make, but there are also some negative aspects. Although there are several types of Udon, typical Udon dishes do not include enough vegetables. In fact, people in Kagawa rarely eat vegetables because they eat Udon for lunch. For vegetable consumption in Japan, Kagawa ranked 47th for men, and 46th for women among the 47 prefectures in Japan. This is a big health issue in Kagawa. People need to realize how Udon can be a contributing factor to health issues. In this section, you can find information about Udon to help you to understand the history of Udon and to help make healthy eating choices.

Sanuki Udon

History

It is believed that the monk Kukai brought noodles to Japan from China. In fact, what is called "Japanese noodles" in Japan exists in almost every country. However, it is thought that the most famous Japanese noodle in Japan is the "Sanuki Udon noodle" of Kagawa Prefecture. Why did Japanese noodles develop so effectively in Kagawa Prefecture?

Kagawa Prefecture is warm and has little precipitation, so it not is a good environment for growing rice, the staple food in Japan. It has been afflicted by bad harvests of rice crops from ancient times. However, this dry climate is suitable for growing wheat. It is thought that the wheat used for Sanuki Udon noodles originated in the Middle East. The Middle East is an arid region and wheat grows with little water. The growth requirements of wheat are a good match for the climate of Kagawa Prefecture. So, it is also thought that the suitability of wheat is considered to be one of the factors that led to the development of Sanuki Udon noodles.

Wheat

Structure

The main ingredient of Udon is starch found in flour. Starch is a carbohydrate and is one of the three major nutrients that the human body requires. The three major nutrients are carbohydrates, proteins, and fats. Gluten, which is contained in flour, is deeply related to the secret of the stickiness of Japanese noodles. Gluten is a kind of protein generated from the albumen of grain, such as wheat and barley. The most important feature of gluten is elasticity. Gliadin and glutenin, which are proteins, react with water, causing the two ingredients to connect. This is gluten, and causes elasticity. Moreover, during Udon making, when the flour dough is allowed to ferment, more gluten is generated and the stickiness unique to Udon is

born. It takes about 30 minutes to 1 hour for gluten formation, which forms a mesh structure. If allowed to "sit" too long, too much gluten is formed and the Udon stickiness is lost.

Inosinic acid

Another important part of Udon is the broth. Dashi is made by boiling Iriko, a small sardine, and is a well-known specialty of Kagawa Prefecture. Many inosinic acids, which are taste ingredients, are contained in Iriko. Inosinic acid is a kind of amino acid, discovered by Kikunae Ikeda in 1907. Amino acids are made from protein. Humans cannot produce amino acids, so they must be ingested through food. Glutamic acid and succinic acid are the key taste ingredients.

Inosinic acid is also found in dried bonito, pork, and fish, while glutamic acid is found in sea tangle, Chinese cabbage, green tea, tomato, and cheese. Succinic acid is contained in dried shiitake mushrooms. So these flavor ingredients bring out the taste of the Udon broth because they contain essential amino acids.

Udon variations from other prefectures

Sanuki Udon is perhaps the most famous Udon in Japan, but there are other types of Udon noodles in Japan. Sanuki Udon is from Kagawa Prefecture and features thick and stiff noodles. Sanuki Udon has a strong chewing texture. Hakata Udon from Hakata, Fukuoka prefecture is thick and soft. Hakata Udon does not have “Koshi”, or firm chewing texture. It is vastly different than Sanuki Udon. Inaniwa Udon from Akita prefecture needs a lot of water to make and feature flat noodles. Hoto from Yamanashi prefecture is a flat and wide type of noodle, usually cooked with vegetables. Pumpkin and long green onion are often used as toppings. Ise Udon from Ise, Mie prefecture is a soft noodle, usually eaten with sweet soy sauce. Kishimen from Nagoya, Aichi prefecture is a flat noodle. Mimi Udon from Kuzu, Tochigi prefecture is uniquely shaped and looks similar to a person's ears. This Udon has a myth: the ears are from bad gods and if someone eats it, the god cannot hear their house’s conversations, keeping evil spirits away.

Differences between Udon and thin Somen

Besides Udon, Kagawa is also famous for the production of Somen. Production of thin wheat noodles is prosperous, especially on Shodoshima. The main difference between Udon and thin Somen is in the form of noodles. Udon is angular, while thin Somen is circular. Moreover, hiyamugi noodles also bear a strong resemblance to Somen. Both Somen and hiyamugi are thinner than Udon noodles.

Somen

Research

Environmental problems in Kagawa

Prof. Takada did research about issues of wastewater caused by Udon. Sanuki Udon has become famous in Kagawa where there are many Udon shops. As a result, it has led to an environmental problem in Kagawa because a large amount of water waste, a byproduct of Udon production, is released as drainage. The drainage contains many starches – ten times more than the amount of starches found in wastewater from ordinary homes. In one shop, 4 tons of drainage is released daily.

The amount of drainage has increased tremendously as the number of Udon products grew. Machines that process drainage are only required at large-scale Udon production faculties that release over 10 tons of drainage. In fact, almost all Udon shops in Kagawa are small, so they are not required to process their drainage. Additionally, in some local areas water drainage systems do not exist, so shops throw drainage directly into a river. Moreover, it costs too much and requires a large space to install a device that can process drainage properly. It is not cost efficient for small shops to pay money for processing drainage. Researchers have to

develop a new device that is cheaper and smaller for local Udon shops.

Isle clean

Processing machines are large because the wastewater must be processed within 12 hours, since Udon shops begin making noodles early in the morning and finish at 4-5 pm. To process that much drainage in such a short amount of time requires a large capacity machine.

Professor. Takada has developed a device called “Isle clean” that uses a Smaller and more cost efficient device to process the drainage. However, there are still challenges to overcome.

Research on the texture of Udon

Professor. Gotani has conducted research about Udon and other foods. His focus is on the texture of food – hardness, softness, stickiness and so on. It is easy to imagine the importance of texture by thinking of the Koshi, the firm chewing texture, of Udon. Udon that is just boiled and Udon that was boiled few hours ago have the same chemical components. However, the former is preferable because it has a good chewing texture. It is easy to understand why texture plays an important part of the eating experience. The process of eating food, which all

people do often unconsciously, is complicated. People bite food, chew it and secrete saliva at the same time to break it down to adequate sized lumps to swallow. This lump assists digestion. If the lump does not contain enough water, it will come apart and be hard to eat. Interestingly, it is not good to cut food into pieces because elderly people may swallow it by mistake and choke. Moreover, making it into a paste is also ineffective because texture is lost and the food will not "feel" delicious. It is important, but difficult to achieve a balance of delicious food and food that is easy to eat. Prof. Gotani is developing new food for elderly people that meets these difficult requirements.

Faculty of Agriculture, Kagawa University

The Future

In the research section, there is information about drainage. As you know, drainage is an environmental problem in Kagawa. However, technology that can address this issue is being developed at Kagawa University. There are two main goals. The first is to solve some of the environmental problems caused by the drainage of Udon shops. The second is to develop a new ecosystem that can

address the issue of starch as a resource for biomass energy from drainage. In addition, they have four concepts for developing the device. First, they place emphasis on processing the drainage that contains a great deal of organic matter. Second, the device can correct starch from less than 200 L drainage per day and purify them at the permitted level of Chemical Oxygen Demand (COD) in less than 12 hours. Third, family-owned shops can use the device in a small space because of its low purchase price and low running cost. Fourth, corrected starch is easy to convert into regenerated energy and rare sugar. With these goals and concepts, Prof. Takada started his research. At first, Prof. Takada used charcoals for processing drainage but it was difficult to process the water in a short amount of time, and an environmentally friendly method for disposal of charcoal needed to be developed. This is why they combined two methods to make a new machine. The first method is to absorb starch by using okra, a plant that can consume the starch as a nutrient. If Udon shops use okra, starch in drainage water can be reduced. The second method is a biochemical process that uses microbes that can decompose starch. By using these techniques, a new method may be developed to solve the drainage problem.

Challenges

Modern society

People in Kagawa relatively eat fewer vegetables and have a higher risk of diabetes. Eating Udon is known to raise blood sugar levels because it contains a great deal of glucose, and the typical side dishes served with Udon are also high in glucose. This is a serious problem in Kagawa. As a partial solution, some Udon shops in Kagawa created new menus including Udon with vegetables. One famous Udon shop released a new noodle that contains dietary fiber, the same amount as a whole head of lettuce. This new approach may greatly improve health in Kagawa. However, the number of shops that have taken action on this crucial issue is limited. Therefore, this problem still exists and is becoming an increasingly larger challenge in modern society.

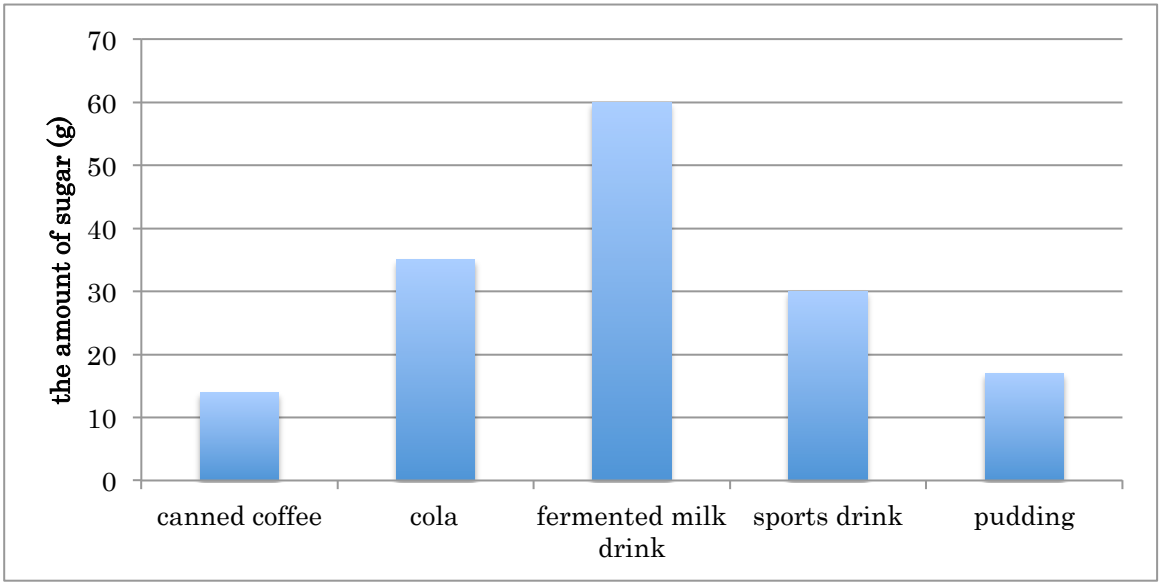
Challenges of the research of drainage

Prof. Takada is developing a new device, but it still has three challenges. The manufacturing and running cost need to be reduced, and the machine size needs to be decreased. Second, the way to use okra has not been perfected. If okra is used, starch still remains in the drainage. Third, it's not enough to develop a new device, but a device that has an overall positive environmental impact is required. Therefore this new device should be able to be used for other purposes such as rare sugar and bioethanol production.

Rare Sugar

Introduction

"Be careful not to overeat sugar, or else you will grow fat." You have probably heard this before. We eat a lot of sugar every day without even knowing it. We eat sugar to live, get energy, and make food taste better. However, too much sugar is not good for our health. It is not possible to judge how much sugar is in a food just by looking at it. So, let's see how much sugar familiar foods contain.



The amount of sugar in food and drink

For example, a 350 ml can of coke typically contains 10 sugar cubes. This means that it has about 30-40 g of sugar.

The sugar contents in coke

It is hard to notice how much sugar one really consumes per day. The World Health Organization (WHO) states that the percentage of sugar in an individual's total daily caloric consumption should supply less than 10% of one's total energy. Furthermore, less than 5% is ideal, which is equal to 25 g of

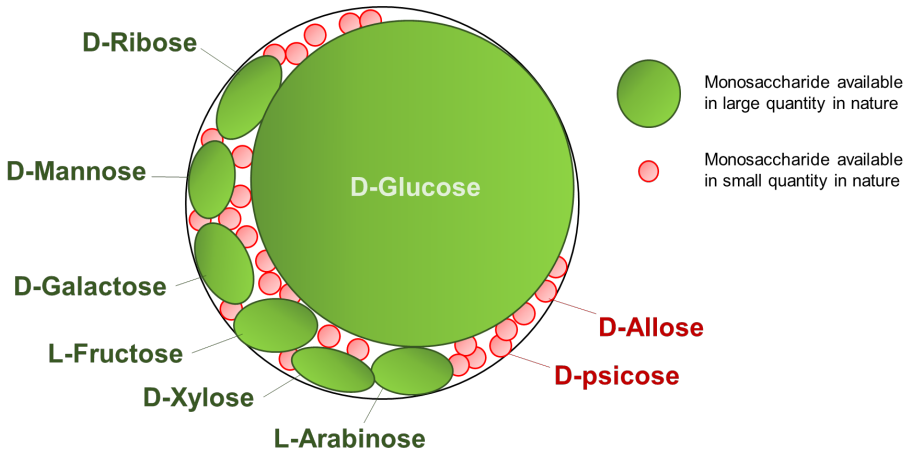
sugar. So, if you drink just one can of soda, you have already exceeded the standard recommendation of daily sugar intake. However, it is difficult to refrain from juice and sweet food. We need a hero to save us from weight gain. This hero is “rare sugar.”

Rare sugar has become famous worldwide. In particular, D-Psicose is the focus of public attention. D-Psicose is one rare sugar. It has 70% sweetness of a normal sugar, yet the caloric value is close to 0 cal. So, it is really a dream sugar.

It is well known that Kagawa Prefecture has the highest number of individuals afflicted with diabetes in Japan, which is a serious health problem. The residents of Kagawa often eat udon, which contains sugar. If we can change the sugar used in udon and other foods to a rare sugar such as D-Psicose, we may decrease the risk of diabetes. Rare sugar may save people throughout the world.

Sugar is one of three major nutrients: protein, lipid and sugar. Carbohydrates taken in from food are digested in the body, decomposed into glucose, then absorbed and used as energy. Sweetness refreshes your mind and body.

Rare sugar is a kind of natural sugar that exists in nature only in very small quantities. However, while the quantity is small, there are a wide variety of rare sugars. In fact, there are about fifty types of rare sugars found in nature.



Relative amounts of sugars found naturally

History

Sugarcane

There is a long history and connection between humans and sugar. It is thought that the cultivation of sugarcane probably began in New Guinea around 6000 B.C. and spread to parts of south east Asia around 4000 B.C. It was introduced to China around 800 B.C. Sugar Cane spread slowly westward, and then to Europe in the mid 700s.

After that, humans gained the ability to manufacture pure sugar. There are many kinds of sugar, such as sucrose, maltose, fructose, but the most famous and most abundant sugar is glucose. Glucose is needed and used by our brains as a source of energy.

Reports on rare sugar began in 1970 by Professor Izumori of Kagawa University. The first report was not about D-Psicose, but rather tagatose. Tagatose is made from Galactose, found in milk.

Before the new rare sugar production method was developed, rare sugar was quite expensive. For example, D-Psicose cost from 40,000 to 50,000 yen per gram. Because most scientists overlooked the potential of rare sugar, there was little to no research being conducted.

Production of rare sugar

Bacteria can produce rare sugars with enzymes. Enzymes make a particular chemical reaction, positive or negative, in a living body. Since 1970, Prof. Izumori and his team focused on this property to discover bacteria that can produce rare sugars. They collected soil samples from many places. At last,

researchers discovered bacteria in the soil at the Faculty of Agriculture of Kagawa University. Then, engineers developed a machine that could culture bacteria to initiate the chemical reaction for mass-production of rare sugar. So rare sugars, which are high-cost can be produced from low-cost sugars, such as glucose.

In 1994, they succeeded in artificially mass-producing rare sugar. Regular sugars such as glucose can be changed into rare sugars by applying enzymes from bacteria. Prof. Izumori discovered that one rare sugar could be changed into another rare sugar with an enzyme reaction. A variety of high quality rare sugars can now be produced.

In 2001, the Rare Sugar Research Center was established at Kagawa University. The Rare Sugar Research Center is the only facility in the world that mass-produces many kinds of rare sugars.

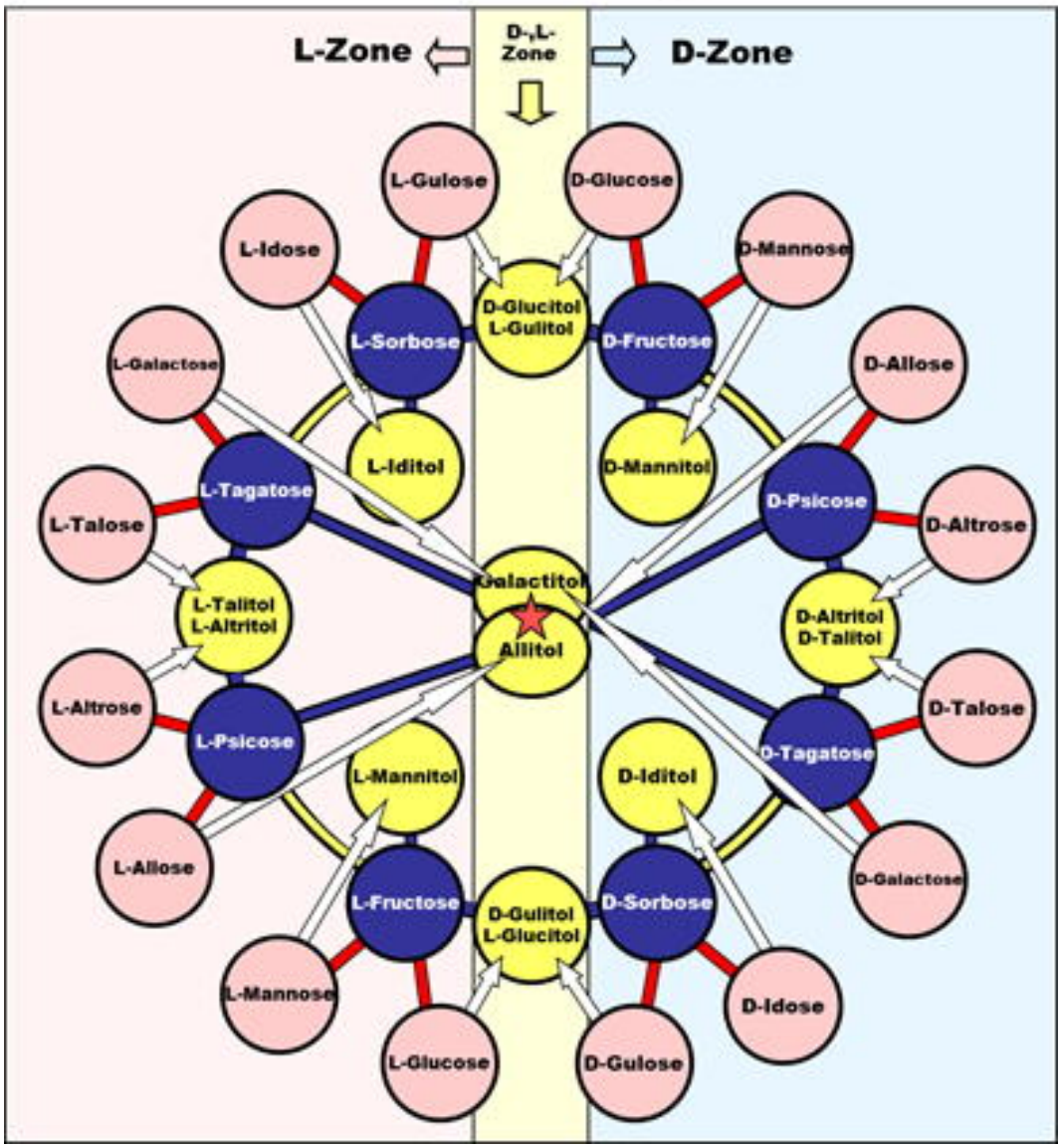
The Rare Sugar Research Center

In 2002, the 1st International Symposium of International Society of Rare Sugars was held in Takamatsu, Kagawa. Researchers from Kagawa University, along with many scientists from around the world, reported their findings on rare sugar at the symposium. Researchers from NASA also took part in the symposium. Then, in 2004, about 120 researchers from all over the world joined in the 2nd International Symposium of the International Society of Rare Sugars. Today, Kagawa is the center of study in the field of rare sugars.

Rare sugars can physiologically influence living beings in various ways. Researchers are developing medicines made from rare sugars. They discovered that rare sugar can affect physical phenomenon in plants and are developing agrichemicals made from rare sugar. It is made from natural sources, so it is eco-friendly. They are now studying how to produce rare sugar more efficiently. Recently, plants that can produce rare sugars have been discovered. Kagawa University is actively promoting the benefits of their research to spread information globally. Some companies have developed products containing rare sugar such as soda, syrup, and some sweets.

Izumoring

Izumoring describes the production of rare sugar based on data from studies. As we can see in the chart below, lines connect thirty-four kinds of saccharides to each other. The lines represent an enzyme reaction between two saccharides. Any kind of rare sugar that is connected by a line on the chart can be produced from another saccharide with enzymes. Therefore, low-cost and readily available sugars, such as D-glucose and D-fructose, can changed into high-value and less commonly available sugars, such as a rare sugar, like D-Psicose.


L-Zone
D-,L-Zone
D-Zone
L-Gulose
D-Glucose
L-Idose
D-Mannose
D-Glucitol
L-Gulitol
L-Sorbose
D-Fructose
L-Galactose
D-Allose
L-Iditol
D-Mannitol
L-Tagatose
D-Psicose
L-Talose
D-Altrose
Galactitol
L-Talitol
L-Altritol
D-Altritol
D-Talitol
Allitol
L-Altrose
D-Talose
L-Psicose
D-Tagatose
L-Mannitol
D-Iditol
L-Allose
D-Galactose
L-Fructose
D-Gulitol
L-Glucitol
D-Sorbose
L-Mannose
D-Idose
L-Glucose
D-Gulose

Izumoring

Functions of rare sugar

Function of rare sugar in food

Every day, we consume a minute amount of D-Psicose. When any sugar is heated is forms various rare sugars including D-Psicose. However, the minute amount that is consumed is not enough to influence our bodies.

To use rare sugars is quite easy as a food additive or sugar replacement. Rare sugars have up to 90% of the sweetness of other sugars, such as sucrose. They are usable in all foods and do not add a heavy taste. For example, when replacing sugar with D-Psicose in sponge cake, the cake becomes softer, more resistant to oxidation, and the egg smell decreases. D-Psicose has many practical applications because it has high processing properties and storage stability.

D-Psicose also can be used with fermented foods. D-Psicose affects the function of lactic acid bacteria and alleviates acidity while increasing mellowness or stickiness. In addition, D-Psicose also affects the function of yeast. So, utilization for fermented food has great potential.

To summarize, D-Psicose has good performance for various foods. Rare sugar improves not only taste but also food texture.

Function of rare sugar in plants

“Rare sugar can also improve crop production as a natural agricultural pesticide, herbicide or fertilizer!”

As we learned in the previous section, rare sugar is a sweetener that is good for your health because it contains up to 90% of the sweetness of sugars, such as sucrose but no calories. However that is not all. Rare sugar also affects plants.

Agricultural chemicals and fertilizer using rare sugars have been developed in the Faculty of Agriculture of Kagawa University. Rare sugar has two remarkable characteristics: one is its ability to strengthen resistance against pests, and the other is its ability to control the growth of plants.

Researchers at Kagawa University found that rare sugars could exert an influence on the hormone balance of a plant. Genes gain resistance to diseases by the absorption of rare sugars, such as D-Psicose or D-Allose. Furthermore, the growth of plants can be promoted or stopped depending on the density of rare sugar. Crops can be safely cultivated by using rare sugar based agricultural pesticides or herbicides because rare sugar exploits the natural functions that plants already have. Moreover, by controlling growth, we can obtain a more reliable supply of crops.

Another practical application is for grass of sports fields. Grass care of sports fields is hard work. However, the growth of the grass can be restrained, reducing the frequency of required trimming by spraying it with rare sugar. This is another reason why rare sugar has a lot of potential. It can be used in many interesting ways, for example, to stunt plants around a runway, road ands so on.

Applications of rare sugar

Many researchers have an interest in the potential of rare sugar for weight loss. When it is substituted for other sugars, rare sugars reduce the calorie intake, an important step in reducing obesity. Therefore, a lot of rare sugar-containing food products are being developed.

For example, one company in Kagawa created syrup containing rare sugar, which has become a popular consumer choice. Consumers use the syrup for cooking instead of table sugar. It has 10% less calories than table sugar. In addition to the reduction of calories, rare sugar blocks the absorption of sugar in the stomach and intestines. Now some companies sell sweets containing the syrup, such as parfaits, cakes, and so on. Moreover, adding rare sugar extends shelf life and adds a higher ant oxidative property.

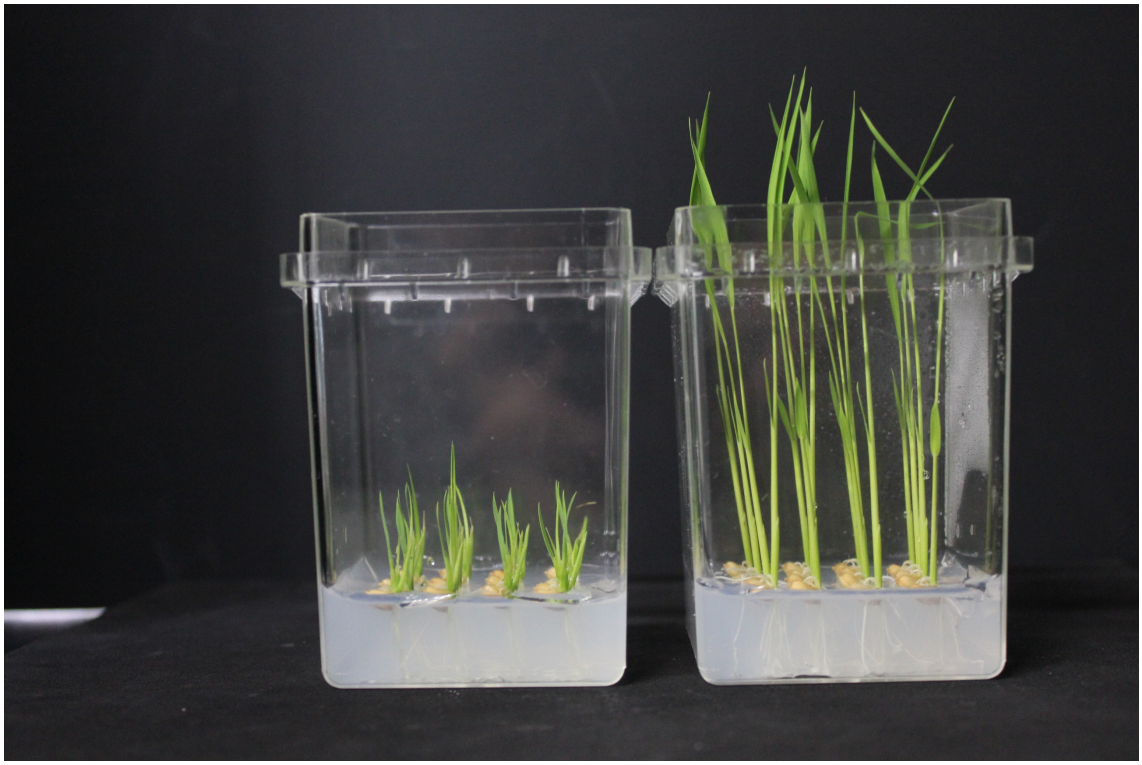
Miracle plant, Zuina

Zuina is a plant living in the mountains of Kyushu, Shikoku, and in the southern Kinki area. The young leaf of Zuina is used as food. A remarkable characteristic of Zuina is that it contains “D-Psicose”, one type of rare sugar. It is said that there are 230,000 species of plants on the earth. However, of all these plants, only Zuina contains and produces D-Psicose. Hence, Zuina is called the “rare sugar tree”.

Zuina

The relationship between Zuina and D-Psicose

D-Psicose blocks signal transmission caused by the growth hormones of plants, which restrains the plant’s growth. Therefore, plants, even weeds, cannot grow in soil that contains D-Psicose. However, Zuina is not affected by signal transmission blockage by growth hormones of D-Psicose because of certain mutations. This is the remarkable characteristic of Zuina. Fallen leaves of Zuina contain D-Psicose. In fact, no other plants can grow in the soil where the Zuina leaves have fallen. Therefore, Zuina can claim its own territory with fallen leaves.



Growth inhibition with rare sugar (left) vs. normal plant growth (right)

Utilizing Zuina

Zuina contains the rare sugar, D-Psicose, so it can be used as food.

Furthermore, in the field of agriculture, by using D-Psicose characteristics as a growth inhibitor, it has become possible to either inhibit or promote plant germination. Therefore, rare sugar has great potential as a natural and harmless agricultural chemical – safe for humans and the environment.

The latest research

Now (2014) research to establish the cultivation techniques of Zuina is underway in the Faculty of Agriculture at Kagawa University. The purpose of the mass production of Zuina is to extract D-Psicose from Zuina, to find enzymes which can be produced more effectively than enzymes previously discovered by Professor Izumori, to sell as food, and so on. In this way Zuina may be able to cover a lot of ground. Zuina is full of possibilities!

Another characteristic, totipotency, is used to produce seedlings of Zuina. Totipotency is a characteristic of a cell to describe its ability to be differentiated into all cells. In other words, it is the potential to create a complete plant organism from just one cell.

Kagawa University has developed a tissue cultivation technique of Zuina, which is difficult to grow from a seed. This is why the technique is needed for the mass production of Zuina.

Researchers who cultivate seedlings of Zuina are elderly, called “komoni Zuinas” living in Miki-cho, Kagawa Prefecture. They grow Zuina, and are filled with hope for the potential of Zuina. Anyone who would like to experience the cultivation of Zuina or wants to know more about the latest research can visit the Akimitsu Laboratory in the Faculty of Agriculture at Kagawa University.

New research on Rare Sugar production

In the Faculty of Agriculture of Kagawa University, a team developed Izumoring and succeeded in mass-producing a variety of rare sugars. However, some rare sugars are not easily produced with Izumoring. Therefore, researchers are seeking a new way to produce those rare sugars. Rare sugars produced with Izumoring are derived from monosaccharide. Some researchers are developing a new method of producing rare sugars from low-cost disaccharides, such as maltose or lactose. After the disaccharides are modified, enzymes hydrolyze it into two monosaccharides, in turn creating rare sugar.

Rare Sugar Production Research Institute

Bioactivity with Rare Sugar

Rare sugar is able to influence a living creatures and induce specific chemical reactions, which is called bioactivity. For example, at the Faculty of Agriculture at Kagawa University, researchers study the bioactivity of rare sugars on eelworms, *Caenorhabditis elegans*. These eelworms only have about a three-week lifespan, so research with *C. elegans* proceeds smoothly. In one experiment, adding D-Psicose to *C. elegans* caused their lifespan to increase. It shows that D-Psicose may have the potential to induce anti-aging effects.

Conclusion

We would like to ask you the same question from the first page of the book, one more time:

"What is Kagawa? "

Now that you have finished reading this book, you can answer the question. You now can understand the story of Kagawa through water, Udon and rare sugar. We are sure that you have noticed that all stories interact with each other and also with other aspects unique to Kagawa. You should be familiar with other features of Kagawa. It is important to understand things from many viewpoints, especially from a scientific perspective, and also an agricultural perspective. Of course we want you to learn accurate information to share with other people.

We hope you have learned many things about Kagawa through science and English.

Now, it is your turn to tell the stories to your friends from all over the world. You have enough knowledge to explain about Kagawa in English.

So please help others to discover Kagawa through English and science!

The Kagawa University Student Development Project Team

Keisuke Hashii, Tomomi Hasegawa, Nao Idegami, Mai Kadota, Moei Taniguchi, Taku Toyama and Daichi Toyonaga

Discover **KAGAWA** through English and Science

Each unit in ***Discover Kagawa through English and Science*** has a science or English related theme that is illustrated and developed through three topics.

- Rare Sugar: Fascinating field of research in food science investigated in Kagawa University
- Water: Essential element of whole lives
- Udon: Traditional food made from wheat and salt

Variable topics help you to express Kagawa to foreigners.

Discover Kagawa through English and Science is fully supported by Aggie Students and Professors of Kagawa University .

A Kagawa University Student Project