

# Development of ESD Materials on Biological Environment Using the Tropical Fruit Cacao

By

Yukako ABE\* and Eriko KUMAZAWA\*\*†

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**Summary** : Cacao beans are essential for the production of chocolate, which is widely consumed around the world. However, there are only a limited number of suitable areas for cacao cultivation, and there are still few examples of cacao cultivation in Japan, so there are few opportunities to see cacao as a plant. Activities and learning about cacao, which is cultivated in a different environment and culture, can serve as an opportunity to deepen understanding of cacao farmers, and thus become an ESD (Education for Sustainable Development) material that promotes multicultural understanding and may contribute to the achievement of the UN's SDGs Goal 12: "Responsible Consumption and Production." Therefore, the purpose of this paper is to consider ESD materials using cacao, the tropical fruit, at an agricultural high school, which is one of the schools that teach vocational subjects and deal with food-related contents. In the cultivation of cacao seedlings, we were able to observe flowering after 4 years. By allowing students to experience the difficulties and current state of cacao cultivation in tropical regions through cacao cultivation in Japan, we were able to foster a sense of accomplishment and a sense of responsibility for cultivation among the students. This experience will provide an opportunity to learn about the current situation of local farmers in the process of cacao bean cultivation and is thought to promote multicultural understanding. This experience may lead to a sense of values and actions to conserve food, as well as to see the world's issues and current situation as one's own, and thus tropical fruit cacao as an ESD teaching material, including cacao cultivation, can be considered as a teaching material for human resource development that contributes to the formation of a sustainable society. In the bean to bar production using 2 types of cacao beans, new findings and insights of the students were confirmed from the perspective of food chemistry. In the future, the ratio of skim milk to cacao butter needs to be adjusted, since the ease of chocolate melting was an issue. A simultaneous study, the "Cacao Girls" project, using cacao as ESD material, showed there was an educational effect. The reason why this project was started was so that the other students could become familiar with cacao. In addition, since fermentation is involved in the production of cacao beans, there is a possibility that the relationship between fermentation and microorganisms can be further utilized in the subject "Microbial Utilization," and further research will be conducted on the use of cacao as an ESD material in agricultural high schools.

The cultivation of cacao, the tropical fruit, and the production of bean to bar using cacao beans, a processed product of cacao, are ESD materials for lifelong learning, not only for students in agricultural high schools. In order to use cacao as ESD material, it is necessary to establish a cultivation method that is suitable for the climate and environment of Japan, and further research is needed on cacao cultivation in Japan, on which there is still a lack of research.

**Key words** : tropical fruit, cacao, ESD, agricultural high school, bean to bar

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\* Department of Ecological Symbiotic Science, Graduate School of Agriculture, Graduate School of Tokyo University of Agriculture

\*\* Teacher-training and Scientific Information Course, Tokyo University of Agriculture

† Corresponding author (E-mail : erico-ku@nodai.ac.jp)

## 1. Introduction

Since the adoption of the Transforming our World: The 2030 Agenda for Sustainable Development by the United Nations in 2015, businesses, local governments, and educational institutions have begun to take concrete steps toward achieving Sustainable Development Goals (SDGs) in an effort to achieve sustainable development<sup>1)</sup>. As an example, Meiji Co., Ltd. has set a goal of achieving a 100% procurement ratio of sustainable cacao beans by FY2026 in order to contribute to the realization of sustainable cacao bean production through improving the environment surrounding cacao bean production areas and farmers<sup>2)</sup>. The Environmental Research Group at Aomori Prefectural Nakui Agricultural High School is developing environmental and agricultural technologies from the perspective of an agricultural high school with the goal of delivering safe and secure water and food to developing countries and was the first agricultural high school to receive the SDGs Promotion Vice President (Chief Cabinet Secretary) Award at the 4th Japan SDGs Awards<sup>3)</sup>. In this way, there are many reports of efforts to achieve SDGs focusing on cacao or efforts related to SDGs at agricultural high schools.

On the other hand, the promotion of Education for Sustainable Development (ESD) is expected to contribute to the achievement of all SDGs<sup>4)</sup>. The “SDGs Action Plan 2021” announced by the SDGs Promotion Headquarters in February 2021 describes priority issues for 2021 as, “IV. Accelerating action through the fulfillment of the potential of each individual and the strengthening of ties.” It is newly specified that SDGs should be disseminated to the next generation through the promotion of ESD<sup>5)</sup>. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has clearly stated in the preamble and general provisions of the new Courses of Study announced in 2018 that “creators of a sustainable society” should be nurtured, and further enhancement of ESD is required in the future<sup>6)</sup>.

As part of vocational education, agricultural high schools have been aiming to produce human resources that can support society and industry. However, with the progress of science and technology, globalization, and changes in industrial structure, developing the specialized knowledge and skills required has become an issue. Among those issues, the subject “Fruits Production and Management” is designated as a subject belonging to the “field related to agricultural production and management” in which students learn about fruit production and management. One of the aims of the course is to examine the subject from the perspective of agricultural management and foster a sense of management through

the development of a sixth industry.

Cacao trees (*Theobroma cacao*, Malvaceae) are evergreen trees and are cultivated worldwide, mainly in tropical and subtropical regions within 20 degrees north and south latitude, including the African continent, as raw material for chocolate<sup>7)</sup>. Cacao trees can only be grown in a limited environment with a minimum temperature of 18°C, optimum annual rainfall of 1,500-2,000 mm, 75% shade, and fertile clayey, well-drained soil with a pH of 5.0-6.5<sup>8)</sup>. In Japan, the Ogasawara Islands, Amami Islands, and Okinawa Prefecture are suitable for cultivation, and there are records of experimental cultivation in Japan, mainly in those areas<sup>9)</sup>. Although there are examples of cultivation in greenhouses using hot spring heat, mass, stable production of cacao beans in Japan has not been achieved to date<sup>10, 11)</sup>. Cacao beans are the fruits harvested from cacao trees (cacao pods), which are fermented and dried in the cultivation area, and are the raw material for beverages and confectioneries, such as chocolate, which are widely distributed and consumed in the world today. Japan imports about 48,000 tons of cacao beans annually as of 2019<sup>12)</sup>. Considering the effects of global warming, there is a possibility of commercial production of cacao seedlings in Japan in the future.

Although there are many examples of corporate initiatives focusing on cacao and practical cases of SDGs and ESD in agricultural high schools, there has been no research on the development of educational materials for ESD in agricultural high schools using tropical fruit. Agricultural high schools are equipped with facilities for cultivation and are more likely to address environmental and food-related issues than regular high schools or compulsory education courses. Cacao is a cash crop and requires many processing steps to be eaten as chocolate. The cross-curricular study of “Fruits Production and Management”, “Microbial Utilization”, “Food Production”, and “Food Chemistry” may contribute to the development of a sense of management through the sixth industrialization. Therefore, we researched ESD materials using cacao, the tropical fruit, in agricultural high schools.

## 2. Materials and methods

### (1) Survey target

This survey was conducted at Ibaraki Prefectural Mito Agricultural High School (Naka City, Ibaraki Prefecture, hereinafter referred to as “Mito Nō”). Mito Nō is one of the oldest and most traditional schools in Ibaraki Prefecture, with 882 students enrolled (as of April 2021)<sup>13)</sup>. The school was established in 1895 as the Central Agricultural Training Center of Ibaraki Prefecture and is 126 years

old as of now. The school has a total of 8 departments: 7 full-time departments (Agriculture, Zoology, Horticulture, Life Science, Agricultural Engineering, Food Manufacture, and Agricultural Calculation) and 1 part-time department (Agriculture). The target persons in this survey belong to the Department of Food Manufacture. Some of the students engage in an agricultural club activity, FFJ (Future Farmers of Japan) and cultivate cacao seedling.

## (2) Greenhouse cultivation and soil comparison test of cacao seedlings

75 pots of cacao, a tropical fruit, whose origin was the Philippines, have been cultivated in a greenhouse at the Horticulture Department of Mito Nō from August 2018 to July 2021. The wetness of the surrounding cacao pulp was removed using rice husks, and only cacao seeds that had already started to sprout were selected. Then, one cacao seed was sown in each polythene plant pot (polypot) No. 3 (9cm diameter pot) filled with Takii seed-starting medium (Takii Seeds Co., Ltd.). 21 days after sowing, the seedlings were repotted in polypot No. 5 (15 cm diameter pot) using Yokabaido (Hokkaido Peat Moss Co., Ltd.), and growth surveys were started. The cacao seedlings were repotted in July 2019 and August 2020 as they grew, and now 52 pots are being grown in polypot No. 6 (18cm diameter pot), 19 pots are in polypot No. 10 (30cm diameter pot) and 4 pots are in polypot No. 16 (48 cm diameter pot). A heated space covered with vinyl was created in a glasshouse (21 m<sup>2</sup> area, single building, east-west orientation), and the temperature was set at 20°C. From October to May, a small hot air blower KA-125 (Nepon Co., Ltd.) was used for heating (Table 1). Foliar and soil watering was done only when the soil was dry, about once a day.

In order to investigate the suitability of the soil for the

**Table 1** Air temperature and humidity in the greenhouse

	air temperature°C			humidity%		
	maximum*	minimum	average <sup>*1</sup>	maximum	minimum	average
Jan	27.95	16.92	22.43	69.71	29.27	49.49
Feb	29.08	18.11	23.59	67.32	33.07	50.19
Mar	30.97	18.57	24.77	74.80	31.76	53.28
Apr	32.05	19.15	25.60	80.98	32.77	56.87
May	34.06	19.45	26.76	93.22	36.53	64.88
Jun	34.57	20.40	27.49	96.46	42.86	69.66
Jul	38.59	22.67	30.63	97.27	40.35	68.81
Aug	41.84	24.86	33.35	95.40	30.95	63.18
Sep	38.91	20.61	29.76	94.61	32.13	63.37
Oct	33.45	18.06	25.75	91.91	37.98	64.95
Nov	31.31	16.96	24.13	81.34	38.05	59.70
Dec	29.77	15.99	22.88	73.94	24.41	49.18
average	33.54	19.31	26.43	84.75	34.18	59.46

\* The maximum and minimum temperatures are shown as monthly averages.

<sup>\*1</sup> For the average value, the average maximum and minimum temperatures for each year are divided by the number of years the measurements were taken.

Japanese climate, growth studies were initiated using different soil formulations. We used humus and red soil and divided the soil into five test plots with differing volume ratios (10:0, 7:3, 5:5, 3:7, and 0:10), and conducted a one-year study from August 2020 to July 2021. Students belonging to the Department of Food Manufacture and participating in an agricultural club activity were assigned to be in charge of the growth surveys, which were conducted once a week. This activity has been started by the girls' students called "Cacao Girls", who are now joined by the boys called "Cacao ambassador". The experimental results obtained were analyzed using spreadsheet software (Microsoft Excel 365) for statistical analysis of the data. For comparison of the means of each test area, an *F*-test was used to confirm equal variances, and an unpaired *t*-test was used.

## (3) Production of bean to bar chocolate

The bean to bar chocolate manufacturing process is an integrated process from cacao beans to the production of chocolate bars. Cacao beans are harvested from cacao pods and are fermented locally for about a week, so beans from each region have a different taste and aroma. Fermentation is affected by the temperature and humidity of the region, as well as a variety of microorganisms rooted in the local plants such as acetic acid bacteria and lactic acid bacteria. By changing the origin of the cacao beans, it is possible to produce chocolate unique to the country<sup>14)</sup>. Bean to bar is currently attracting attention as one of the approaches to connect producers with overseas cacao bean producing areas that were previously too far away to be engaged. In this project, we tried to make the first bean to bar chocolate in an agricultural high school using cacao beans from Ghana and Indonesia (Tachibana Shoten Co., Ltd.).

The process for making bean to bar chocolate was as follows. First, 110 g of cacao beans fermented and dried in their respective regions were roasted over medium heat for about 10 minutes. The outer skin was then removed to make cacao nibs. 85 g of cacao nibs were obtained from 110 g of cacao beans. These cacao nibs were pulverized into a fine paste using the New Yomekko cutter (Yamamoto Electric Co., Ltd.) to make cacao mass. After that, 40 g of skim milk, 30 g of powdered sugar, and 20 g of cacao butter were added, and the mixture was ground again until smooth, and finally poured into a mold to cool and solidify. This time, no conching to make the texture smooth and no tempering to make the fat crystals uniform were used.

## (4) ICT-based ESD using cacao as a teaching material

While working on this project related to cacao, we

realized that since only some of the students involved in the project can be expected to benefit, we included a class practice using cacao as teaching material for ESD. On Tuesday, November 10, 2020, 40 students of the 3rd grade of the Department of Food Manufacture participated in an ICT-enhanced class entitled “Types and Characteristics of Microorganisms: Realization of Proactive, Interactive and Deep Learning Using Cacao as a Teaching Material” in the subject “Microbial Utilization” as part of the “Ibaraki High School Academic Achievement Promotion Comprehensive Project”<sup>15)</sup>. The goal of this class was to explore the possibilities of microorganisms through chocolate (cacao), a teaching material as a fermented food, by applying knowledge of the forms and characteristics of fungi, bacteria, yeasts, and viruses that the students had learned about so far. In the class, a worksheet prepared in advance was used, and the answers were selective, so that the students could perform sensory evaluation of bean to bar within a limited time (Fig. 1, Fig. 2).

As an introduction of the study plan, one of the authors introduced the cacao project (“Cacao Girls”) whose classmates were working on as a project learning theme. In the development of the study plan, the bacteria involved in the fermentation of cacao beans were introduced in the order of the microorganisms

involved in the fermentation, along with a table on the aerobic plate count in “Microorganisms in Fermentation of Cacao Beans”<sup>16)</sup>. The objective was to raise student awareness of the differences in aroma and fermentation by smelling the aroma of 2 types of cacao beans first and then having students answer the sensory evaluation of beans to bar made from each type of cacao beans. The production of bean to bar was done in the same way as in “(3) Production of bean to bar chocolate” above, using 2 types of cacao beans from Ghana and Indonesia. 8 students from the same class were involved in the production of the chocolate through “Project Study,” and the students tasted the bean to bar chocolate produced by their classmates. As for final review, the students answered to the class evaluation through online learning system Google Forms, Google Classroom (Google, Inc.).

### 3. Results

#### (1) Overwintering and Flowering of Cacao Seedlings

In July 10, 2021, the 4th Japanese summer, a 110 cm tall cacao seedling produced flower buds for the first time (Fig. 3). This cacao seedling had been repotted in August 2020 from a No. 6 pot to a No. 10 pot with mixed soil (humus to red soil = 4:6). Since then, flowering has been observed several times in three cacao seedlings. However, since the flowers drop within a few days after

The microorganisms behind delicious chocolate

M3 Name \_\_\_\_\_

—The process from harvesting mature cacao pods to making cacao beans —

Chocolate and microorganisms . . .

Chocolate is ( \_\_\_\_\_ ), Proper ( \_\_\_\_\_ ) stimulates cacao beans to produce the ( \_\_\_\_\_ ) of the aroma, then after ( \_\_\_\_\_ ) chocolate has a good aroma.

—What kind of microorganisms are involved in the fermentation of cacao beans?—

① \_\_\_\_\_

② \_\_\_\_\_

③ \_\_\_\_\_

④ \_\_\_\_\_

⑤ \_\_\_\_\_

○ :    ◇ :  
□ :    △ :  
● :

Fig.1. The Microbiology of Cocoa Fermentation and Its Role in Chocolate Quality Rosnee F. Schwan, Alan E. Whelan (2004)

—The characteristics of cacao bean aromas—

Cacao beans from Ghana	Cacao beans from Indonesia
(For example)	(For example)

※ Let's try to fill in the form while focusing on the differences between the Ghanaian and Indonesian cacao bean aromas.

—Preference-type evaluation of chocolate (–dislike +like) —

Cacao beans from Ghana

Cacao beans from Indonesia

overall evaluation

7-point rating scale from –3 (dislike) to +3 (like) including 0

—Conclusion—

- Chocolate is a type of ( \_\_\_\_\_ ), and various microorganisms are involved.
- When the appropriate fermentation process is carried out, the unique aroma of chocolate is produced as the cacao beans are ( \_\_\_\_\_ ).
- The microorganisms involved in the fermentation of cacao beans are ( \_\_\_\_\_ ) → ( \_\_\_\_\_ ) → ( \_\_\_\_\_ ) → ( \_\_\_\_\_ ) → ( \_\_\_\_\_ ) → ( \_\_\_\_\_ ) → ( \_\_\_\_\_ )

Fig. 1 Work sheet of “The microorganisms behind delicious chocolate”

The microorganisms behind delicious chocolate

M3 Name \_\_\_\_\_

—The process from harvesting mature cacao pods to making cacao beans —



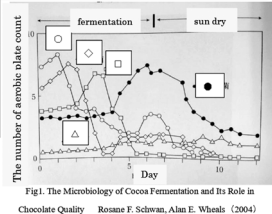
Chocolate and microorganisms . . .

Chocolate is ( fermented food ) . . . Proper ( fermentation ) stimulates cacao beans to produce the ( origin ) of the aroma, then after ( sun drying ) chocolate has a good aroma.

—What kind of microorganisms are involved in the fermentation of cacao beans?—

<p>① <u>yeast</u> It starts fermentation under anaerobic conditions. The sugar (glucose) in the pulp is used for alcohol fermentation to produce ethanol.</p>
<p>② <u>lactic acid bacteria</u>. Anaerobic lactic acid bacteria grow as well as yeast.</p>
<p>③ <u>acetic acid bacteria</u> A little bit of air gets in cacao beans then, acetic acid bacteria, which is aerobic bacteria, grow on ethanol, which is generated by yeast as a substrate.</p>
<p>④ <u>spore forming bacteria</u></p>
<p>⑤ <u>fungi</u> After fermentation, if not sun dried properly, fungi will develop as mold during storage and transportation.</p>

○ : yeast   ◇ : lactic acid bacteria  
□ : acetic acid bacteria   △ : fungi  
● : spore forming bacteria

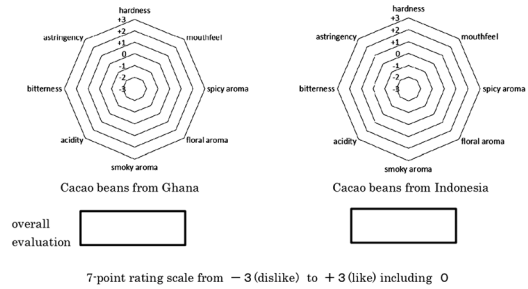


—The characteristics of cacao bean aromas—

Cacao beans from Ghana	Cacao beans from Indonesia
(For example) The smell of beetles Clear chocolate smell Acidity Roasted almonds smelly	(For example) More acidic than Ghanaian Stronger smell than Ghanaian Like natto (fermented soybeans) Foot odor More chocolatey smell than Ghanaian

※ Let's try to fill in the form while focusing on the differences between the Ghanaian and Indonesian cacao bean aromas.

—Preference-type evaluation of chocolate (—dislike +like)—



—Conclusion—

- Chocolate is a type of ( fermented food ), and various microorganisms are involved.
- When the appropriate fermentation process is carried out, the unique aroma of chocolate is produced as the cacao beans are ( roasting ).
- The microorganisms involved in the fermentation of cacao beans are ( yeast ) → ( lactic acid bacteria ) → ( acetic acid bacteria ) → ( spore forming bacteria ) → ( fungi )

Fig. 2 Answer of work sheet “The microorganisms behind delicious chocolate”



Fig. 3 Blooming cacao flower

flowering, the plants have not yet set fruit. In addition, many aphids' infestations were observed in April 2021.

The frequency with which students went to observe the plants increased as the months went by, and students were seen pointing out to each other those who forgot to do their duty<sup>17)</sup>. The students developed a

sense of responsibility for cultivating rare plants, and new values and behaviors that led to the solution of problems were observed.

(2) Results of soil blending test

In the study with different proportions of humus and red soil, the highest growth of 28.3 cm was observed in “3:7” test plot II with the ratio of humus and red soil (Table 2). However, the “7:3” test plot showed the highest growth among the 5 test plots with an average growth of 12.4 cm in 4 replicates and a total of 49.7 cm.

A two-tailed t-test was conducted at a 5% significance level to see if the “10:0” and “7:3” test plots were statistically significant.  $t(6) = 0.32, p = .75$ , indicating that there was no significant difference between the “10:0” and “7:3” test plots.

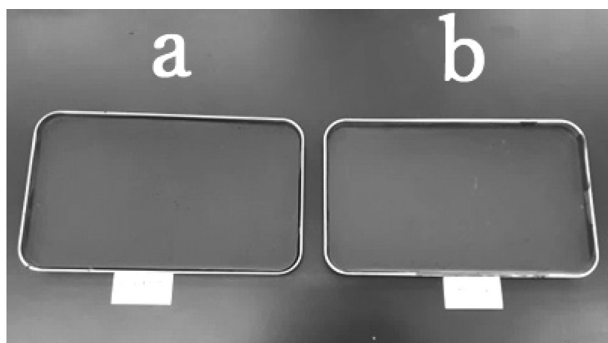
(3) The first bean to bar production at an agricultural high school in Japan

We had the ability to establish a method for bean to bar production, although it was still rough to the mouthfeel (Fig. 4). However, if the beans are held in the hands for just a few minutes, they begin to melt quickly depending on the temperature, so the ease of melting became an issue in the summer. In the future, the ratio of cacao butter to skim milk needs to be adjusted.

**Table 2** Cacao seedlings growing test of comparative humus and red clay rate

repeat	10:0*				7:3				5:5				3:7				0:10			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
24.Aug.2020	43.4 <sup>*1</sup>	69.7	54.5	56.5	53.5	62.0	72.0	49.7	68.6	56.5	52.5	66.0	48.9	69.0	58.0	68.9	52.5	70.0	59.0	69.5
6.Jul.2021	58.1	83.2	62.1	67.0	68.0	79.2	80.8	58.9	77.5	71.8	56.3	77.7	55.3	97.3	60.0	75.7	64.8	88.6	64.8	72.8
growth	14.7	13.5	7.6	10.5	14.5	17.2	8.8	9.2	8.9	15.3	3.8	11.7	6.4	28.3	2.0	6.8	12.3	18.6	5.8	3.3
growth average	11.6				12.4				9.9				10.9				10.0			
growth total	46.3				49.7				39.7				43.5				40.0			

\* humus : red clay <sup>\*1</sup> cm



**Fig. 4** bean to bar chocolate  
a: cacao beans produced in Indonesia  
b: cacao beans produced in Ghana

The bean to bar process, which involves the entire process from roasting cacao beans to making chocolate bars, greatly stimulated the curiosity of the students, especially since the aroma produced during the roasting process varies greatly depending on the region the beans are from. In the process of melting cacao butter by pulverizing cacao beans, students were surprised to see solid cacao beans become liquid like chocolate and we found that cacao could be a teaching material to make them think about oil crystals and the melting of oil.

#### (4) Educational effects of using cacao as ESD material

Since the “Cacao Girls” were part of the class, they became pivotal members during this study. The students around them asked the “Cacao Girls” questions about cacao, which stimulated the “Cacao Girls” curiosity and motivated them to work on the project.

Cacao is a tropical fruit that can only be cultivated in tropical regions, and the fermentation process is carried out locally before it is exported to chocolate producing countries. For this reason, it has been difficult to experience fermentation. The aroma and taste of cacao beans are related to the humidity and microorganisms of each country<sup>18, 19</sup>. The microorganisms involved in the fermentation of cacao beans range from bacteria to fungi depending on whether they are aerobic or anaerobic microorganisms. As mentioned above, since fermentation

is involved in the production of cacao beans, there is a possibility that the relationship between fermentation and microorganisms can be further utilized in the subject “Microbial Utilization,” and further research will be conducted on the use of cacao as an ESD material in agricultural high schools (Table 3).

To provide a place where students, who were usually influenced by the opinions of those around them and had difficulty expressing their own opinions and ideas, could express their individual thoughts by using the online learning system, ICT material as the conclusion of this study. However, by conducting class evaluation after the class, it is possible that the effect of the reflection may have decreased. The future challenge is to find a way to combine online materials with face-to-face classes.

## 4. Discussion

Although there is a lack of data on cacao seedling cultivation in Japan, we can conclude that cacao seedlings can be cultivated in a heated greenhouse in the Kanto region in winter. Since flowering was observed in the 4th year of cultivation, we can predict the possibility of bearing fruit in the future, and if bearing fruit becomes possible, cacao will be even more attractive as ESD teaching material. In order to achieve further flowering and bearing fruit next year, it is necessary to reveal the mechanism of the pollination method. My future research is to devise a pruning method to adjust the height of the cacao trees.

Sato and Sakaguchi reported that flowering is related to rainfall, and that flowering, and pollination occur in all months of the year in greenhouses as well as outdoors<sup>20</sup>. Since flowering was observed for the first time in July, it is necessary to maintain an average temperature of around 27°C, analyze the soil, and investigate the appropriate amount of sunlight for the period from October to December, when pollination is reported to be most favorable.

This may be due to the fact that it is difficult to ventilate the greenhouse in winter from the viewpoint of heat retention, making it a favorable environment for the

**Table 3** The result of questionnaire about the lecture using cacao as ESD material

	yes	no	no opinion	supported by friends and teachers
Did you join this class after learning about the characteristics of each food microbe?	46*	0	0	
Did you learn about the microorganisms involved in cacao fermentation?	44	1	1	
Did you enhance your understanding of fermented food?	45	0	1	
Did you learn about how microorganisms affect food manufacturing?	43	0	3	
Did you log into Google Classroom by yourself?	29	1		16
Did you like how this lecture used PowerPoint as educational material compared to regular lectures?	28	4	14	

\* N=46

breeding of pests.

Cacao seeds can be imported into Japan with a phytosanitary certificate issued by the government agency of the exporting country and inspection by the Plant Protection Station in Japan, depending on the exporting country. However, in the revision of the Enforcement Regulations of the Plant Protection Law in April 2021, the import of cacao pods from major cultivating countries was prohibited from the viewpoint of preventing pests caused by *Bactrocera dorsalis*<sup>21)</sup>. In addition, from the perspective of biodiversity, Japan became a party to the Nagoya Protocol in 2015, and the Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) is further required<sup>22)</sup>. Against this background, if cacao pods can be harvested in the Kanto region of Japan, not only will cacao be useful as ESD material, but research on cacao cultivation in Japan may take a great leap forward. Cacao beans are essential as a raw material for chocolate, but it has been found that the production of flavored cacao beans, which have a distinctive flavor, is decreasing year by year<sup>23)</sup>, and chocolate processing companies are successively working to secure stable cacao beans and support cultivating countries for stable production of cacao pods<sup>19, 24)</sup>. From this perspective, there is a need for further research on cacao, a tropical fruit, in Japan, and it is necessary to continue this research in the future.

Fermentation is deeply involved in the production of cacao beans, and it is expected that cacao will be used as an ESD material in the subject "Microbial Utilization." However, since the fermentation of cacao beans takes place locally in cacao producing countries, it still remains to be seen how students can experience and learn about the fermentation of cacao beans.

Cacao is a tropical fruit tree, and during greenhouse cultivation in Japan, only a small annual growth of about 11 cm was observed. However, after taking over the cultivation of cacao from graduating students and seeing the flowers bloom for the first time in over four years, the students were able to develop a sense of accomplishment in cultivating a rare plant and a sense of responsi-

bility for the cultivation. Cacao is unique in that the flowers and fruits grow on the trunk, and the fruits cannot be harvested until three to four years after cultivation. In other words, income from cacao cultivation cannot be expected until three to four years after the start of cultivation. By allowing students to experience the hardships and current state of cacao cultivation in tropical regions through cacao cultivation in Japan, they will have an opportunity to learn about the current situation of local farmers in the process of cacao bean cultivation. By experiencing the current situation of cacao farmers, which is difficult to encounter in their daily life in Japan, students will be able to promote multicultural understanding, and at the same time, they will be able to see the world's issues and current situation as their own, which will lead to a desire and action to conserve food. In the future, this may lead to the creation of behaviors and values that contribute to the reduction of food waste. In addition, the tropical fruit cacao as an ESD teaching material, including cacao cultivation, can be considered a teaching material for human resource development that contributes to the formation of a sustainable society.

When looking at cacao as ESD material, from the perspective of the food chemistry field of the agriculture department, it is possible to create cross-curricular learning opportunities in the subjects of "Microbial Utilization," "Food Chemistry," "Food Production," "Problem Study," and "Comprehensive Practice," as well as in the subjects of "English," "Home Economics," and "Geography, History, and Civics." Although changing teachers' awareness is one of the challenges in introducing ESD<sup>25)</sup>, focusing on one crop or fruit tree as a cross-curricular or cross-subject learning approach may facilitate interaction in a wide range of subject areas and contribute to the creation of new ideas and insights. Bean to bar makers in Japan held a workshop on handmade chocolate from cacao beans<sup>26)</sup>, and Arboricultural Research Institute, the University of Tokyo Forests held a program on tropical plants using cacao as a seminar for first and second year students<sup>27)</sup>. It can be

considered that cacao can also be used as a subject for lifelong learning for residents. In order to use cacao as ESD material, it is necessary to study a cultivation method that is suitable for the soil and climate of Japan.

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#### References

- 1) United Nations (2015) Transforming our world : the 2030 Agenda for Sustainable Development. New York.
- 2) Meiji Holdings Co., Ltd., Sustainable Procurement, <[https://www.meiji.com/global/sustainability/sustainable\\_procurement/](https://www.meiji.com/global/sustainability/sustainable_procurement/)> (last accessed 12th Aug 2021)
- 3) Ministry of Foreign Affairs of Japan, JAPAN SDGs Action Platform, Aomori Prefectural Nakui Agricultural High School, <[https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/pdf/award4\\_03\\_nakuinougyoukoutougakkou.pdf](https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/pdf/award4_03_nakuinougyoukoutougakkou.pdf)> (last accessed 12th Aug 2021)
- 4) CAROLEE B, HEATHER C (2014) Shaping the Future We Want : UN Decade of Education for Sustainable Development (2005-2014) FINAL REPORT. United Nations Educational, Scientific and Cultural Organization, Paris.
- 5) SDGs Promotion Headquarters, SDGs Action Plan 2021, <[https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/pdf/SDGs\\_Action\\_Plan\\_2021.pdf](https://www.mofa.go.jp/mofaj/gaiko/oda/sdgs/pdf/SDGs_Action_Plan_2021.pdf)> (last accessed 12th Aug 2021)
- 6) Ministry of Education, Culture, Sports, Science and Technology (2018) the Courses of Study for High Schools Agriculture Subject Area. Tokyo.
- 7) POHLAN J, DIAZ V (2010) "Growth and Production of Cacao" *Soils, Plant Growth and Crop Production volume III*. EOLSS Publishers Co Ltd, Oxford, UK, pp.346-377.
- 8) Bureau of Agricultural Research (2011) CACAO. Planting and Farm Establishment. Agricultural Training Institute, Diliman.
- 9) Hiratsuka Confectionery Co., Ltd., TOKYO CACAO, <<https://tokyo-cacao.com/>> (last accessed 12th Aug 2021)
- 10) MIYAZAKI Y, ONO K (1960) Documents of Cacao Growing in Green House. *Trop. Agr. Develop.* 4 : no2 55-63.
- 11) SATO K, SAKAGUCHI N (1967) Studies of Cacao Growing in Green House : On the growth of Cacao-pods. *Trop. Agr. Develop.* 11 : no3 115-119.
- 12) Portal Site of Official Statistic of Japan, <<https://www.e-stat.go.jp/en>> (last accessed 12th Aug 2021)
- 13) Ibaraki Prefectural Mito Agricultural High School (2021) School Guide 2020.
- 14) OSAWA T, KIMURA S, KOYANO T, SATOU K (2015) Science of Chocolate. Asakura Publishing Co., Ltd., Tokyo, pp. 33-40.
- 15) Ibaraki Prefectural Educational Agency, Division of the High School Education, (2020) Ibaraki High School Academic Achievement Promotion Comprehensive Project 2020.
- 16) SCHWAN R F, WHEALS A E (2004) The Microbiology of Cocoa Fermentation and its Role in Chocolate Quality. *Crit. Rev. Food Sci. Nutr.* 44 : 205-221.
- 17) ABE Y, MURAKAMI T, KUMAZAWA E (2019) Practices of ESD in Agricultural High School -A Case Study of Cacao as a Teaching Material-. *Res. Trop. Agric* 12 : extra issue 2 79-80.
- 18) SATO K, SAKIYAMA K (2011) Chocolate and cocoa are fermented foods : Controlling the Fermentation of Cacao Beans Enables the Production of Delicious Chocolate. *Chem. Biol.* 49 : no8 523-526.
- 19) ISHIDA A, SAKIYAMA K, NIHEI M (2020) Product Innovation : The development of “Meiji THE Chocolate” making new value focus on aroma of flavor cacao beans. *Chem. Biol.* 58 : no9 537-543.
- 20) SATO K, SAKAGUCHI N (1968) Studies of Cacao Growing in Green House : II The Nature of Pollen and Pollination Mechanism. *Trop. Agr. Develop.* 12 : no2 79-82.
- 21) Plant Protection Station, The revision of enforcement regulations of Plant Protection Act, <[https://www.maff.go.jp/pps/j/information/seido\\_minaosi/pdf/7ji\\_setsumei.pdf](https://www.maff.go.jp/pps/j/information/seido_minaosi/pdf/7ji_setsumei.pdf)> (last accessed 13th Aug 2021)
- 22) Ministry of Foreign Affairs of Japan, Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity, <<https://www.mofa.go.jp/mofaj/files/000236482.pdf>> (last accessed 13th Aug 2021)
- 23) BANQUERIGO E, CESO V (2017) Philippine Cacao Industry Road Map. Philippine Cacao Industry Council.
- 24) Dari K Co., Ltd., (2017) Cacao Products -Chocolate, Beauty and Wellness-. Dari K Co., Ltd.
- 25) SASAKI O (2021) ESD Practices in Teacher's Expertise, School Management and Support System -research from previous study inside and outside the country-. *Abstracts of the 3rd Annual Meeting of Jpn. Soc. ESD*.
- 26) Minimal -Bean to Bar Chocolate-, EVENT/WORKSHOP, <<https://mini-malt.tokyo/pages/event>> (last accessed 13th Aug 2021)
- 27) Arbicultural Research Institute The University of Tokyo Forests, Graduate School of Agricultural and Life Science, The University of Tokyo, Dipping chocolate in hot springs to soak up skills UTokyo students become deeper thinkers via plant-based activities in subtropical Izu, <[https://www.u-tokyo.ac.jp/focus/ja/features/z1304\\_00075.html](https://www.u-tokyo.ac.jp/focus/ja/features/z1304_00075.html)> (last accessed 13th Aug 2021)



# 熱帯果樹カカオを活用した 生物環境に関する ESD 教材開発

安部由香子\*・熊澤恵里子\*\*†

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**要約:**世界で広く食されているチョコレート製造に欠かせないカカオ豆であるが、栽培適地は限られており、日本での栽培事例は未だ乏しいのが現状で、植物としてのカカオを見る機会は日本では少ない。環境や文化の異なる異国の地で栽培されたカカオを題材とした活動や学習は、生産者であるカカオ農家についての理解を深めるきっかけとして、多文化理解を促す ESD 教材になり、SDGs の目標 12「つくる責任 つかう責任」の達成にも貢献できる可能性がある。そこで、職業に関する教科の一つであり、食品に関する内容を取り扱っている農業高校において、熱帯果樹であるカカオを活用した ESD 教材を研究した。

カカオ苗の栽培では、4年越しで開花を観察することができた。熱帯地域におけるカカオ栽培の苦勞や現状を日本でのカカオ栽培を通じて生徒が実体験することにより、生徒たちの達成感や栽培への責任感を育むことができた。この経験はカカオ豆の栽培過程にある現地農家の現状を知るきっかけとなり、多文化理解を促すと考えられる。世界の課題や現状を自分事と捉え、食べ物を大切にしようという価値観や行動にもつながる可能性があり、カカオ栽培を含めた ESD 教材としての熱帯果樹カカオは、持続可能な社会形成に寄与する人材育成のための教材に成り得ると考察した。2種のカカオ豆を用いた bean to bar 製造では、食品化学の観点から、生徒の新たな発見や気づきが確認された。チョコレートの溶けやすさが課題であったので、今後はスキムミルクとカカオバターの割合を調整する必要がある。カカオを ESD 教材として取り扱った一斉授業では、プロジェクト学習で取り組んでいる課題を一斉授業として取り扱った時の効果が示された。カカオ豆の製造には発酵が関わっていることから、発酵と微生物の関わりについて、科目「微生物利用」の授業で更に活用できる可能性があり、農業高校での ESD 教材としたカカオの活用について、今後も更なる研究を進めていく。

熱帯果樹であるカカオの栽培やその加工品であるカカオ豆を用いた bean to bar の製造は、農業高校での学びにとどまらず、生涯学習としての ESD 教材になると考えられる。カカオを ESD 教材として活用するためには、日本の気候や風土を考慮した栽培方法を研究開発していく必要があり、未だ日本での栽培実績に乏しい熱帯果樹カカオについては、今後も調査研究を継続していく。

**キーワード:** 熱帯果樹, カカオ, 持続可能な開発のための教育, 農業高校, bean to bar

\* 東京農業大学大学院農学研究科環境共生学専攻

\*\* 東京農業大学教職・学術情報課程

† Corresponding author (E-mail: erico-ku@nodai.ac.jp)