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Life Cycle Inventory Analysis of Bagasse Pulp as a Cellulosic Packaging Material

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This paper describes the Life Cycle Inventory (LCI) analysis of bagasse pulp used as raw material for packaging in comparison with that of eucalyptus pulp. An LCI analysis on the bagasse pulp produced from local pulp industry (100,000 Bone dry metric tons) located close to a sugar mill in Thailand was conducted. Eucalyptus (*Eucalyptus globulus*) wood pulp originated from Western Australia was considered as the reference pulp to compare with that of bagasse. These pulps are assumed to be used in Japan as the packaging materials. Carbon dioxide fixation during growing process was included in the LCI analysis in this study. It is demonstrated that total CO_2 emission is 165,209 tCO_2 per year for bagasse pulp while 185,216 tCO_2 per year for eucalyptus pulp in order to provide furnish as packaging materials. The amount of CO_2 absorption is 367,500 tCO_2 per year for bagasse pulp while 294,548 tCO_2 per year for eucalyptus pulp. These results suggest that the use of bagasse pulp, a non-wood biomass resource, as the packaging material has a potential to contribute the reduction of the greenhouse gas emission.

Keywords : LCI, bagasse pulp, eucalyptus pulp, bio-mass resources, paper products, cultivation, plantation, converting, transport, CO_2, carbon footprint

1. Introduction

As the necessities for human living, culture and industries, the large amount of paper products including packaging materials have been consumed continuously with the progress of the living standard. The paper products have a characteristic of sustainable carbon neutral material and a potential to be environmentally friendly. However, as the availability of the wood resources is limited, it will be necessary to find out urgently new resources other than the forest products. Considering such a situation, utilization of the plants classified as non-wood fiber crops such as straw, bamboo, reed, jute, bagasse, etc. have been now attracting great interest.

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Utilization of non-wood fiber crops for packaging materials had been reported on some literatures[3~5] in Japan. In addition, some literatures [6~9] of Life Cycle Assessment (LCA) in the field of pulp and paper production had been published for the imported raw materials such as eucalyptus chip and bagasse pulp as well as the domestic recycled paper in Japan since 2000. However, these literatures did not report details of bagasse pulp which is one of the important non-wood resources.

Bagasse is the fibrous residue of the sugar cane (*Sachcarum officinarum*) disposed after the crushing and extraction process in the sugar mill. Sugar cane is grown in the tropical and subtropical countries to produce sugar and is highly expected as new cellulosic resources and bio-fuel materials in 21st century. A modern bagasse pulp mill of 100,000 Bdmt per year has been operated by Environment Pulp and Paper Company Limited (EPPCO) since 2003. The mill is located close to the sugar mill in Thailand and their bleached chemical pulp of bagasse is exported to Japan as well as to other countries for furnish of a variety of the paper products. The NPO Non-Wood Green Products Association of Japan (NWGP) has been cooperating with EPPCO since 2005 and is in a position to obtain many detailed technical data for bagasse pulp production[1)-2)].

Currently, the discussions on carbon footprint (CPF) that is a new figure of LCA specifically focused on the greenhouse gas emission have been prevailing worldwide. It is essential to calculate the CO_2 absorption and emission in pulp and paper products including packaging materials for providing the basic data to be used in the CFP of these products.

The life cycle inventory (LCI) analysis quantifies the resources use, energy use, and environmental releases associated with the system being evaluated. To develop the inventory, a flow model of the technical system has to be constructed using the data on inputs and outputs.

This paper explains and discusses on the comparative LCI analysis of bagasse and eucalyptus pulps based on the technical survey of the production systems.

2. Materials and Method

2-1. Materials

The purpose of this paper is to calculate amount of CO_2 emission and absorption from bagasse and eucalyptus pulp production line as well as transportation.

Bagasse is the residue from the production of cane sugar. The production amount of cane sugar in Thailand is ranked fourth in the world and the enormous quantity of bagasse has been discharged annually. It is mainly consumed as fuel but some are used as fiber resources. The major obstacle of bagasse for papermaking is the high pith content. The content is about 25% by weight of the bagasse.

Bagasse pulp is transported from the pulp mill to ocean port in Thailand and then exported to Japan by container carrier.

Eucalyptus is processed as wood chip and transported from the chip mill to ocean harbor in Western Australia and exported to chip yard of pulp mill in Japan in bulk.

2-2 .Workflow analysis of bagasse pulp

Fig. 1 shows workflow processes of Kaset Thai Sugar Mill EPPCO Pulp Mill. EPPCO, modern bagasse pulp mill, is one of Ekalack Group in Thailand and offers the chemical bagasse pulp which is made from well de-pithed fresh bagasse from the adjacent Kaset Thai Sugar Co. in Nakhonsawan Province. The pulp is well acceptable for production of paperboard, printing paper, napkin, etc. It is also applied for packaging materials such as pulp mold and plate of 100% bagasse pulp.

There is an experienced assumption that 1,000 t of green (fresh) sugar canes consist of 714 t sugar cane juice, 286 t of bagasse (225 t for fuel and 61 t for Pulp resources) as illustrated.

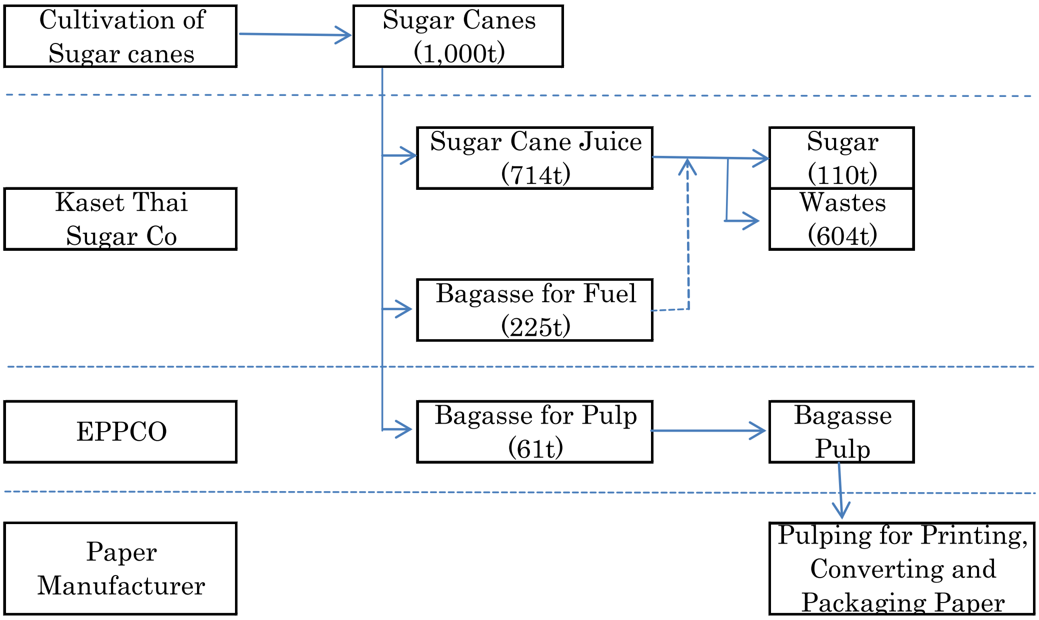

Fig.1 Workflow of Kaset Sugar Co and EPPCO Pulp Mill & Conversion

2-3. Criteria to conduct LCI evaluation of bagasse pulp and eucalyptus pulp

Criteria to conduct LCI evaluation of two kinds of paper pulps are set as follows;

a) Bagasse pulp: Residue of sugar canes after de-pithing from sugar mill is sent to bagasse pulp mill by conveyor for processing of paper pulp and produced pulp is sent to Japan for consumption.
b) Eucalyptus pulp: Eucalyptus tree is planted in Western Australia and its harvesting periods is 10 years.
c) Growing rate of eucalyptus is about 11.0 Bdmt/ha/y and eucalyptus tree is processed there as wood chip after harvesting. Produced eucalyptus wood chip is sent to Japan and processed to paper pulp for consumption.
d) Comparison of both pulps was made on the same production scale of 100,000 Bdmt per year.
e) Total amounts of CO_2 emitted from pulp production in both pulp mills are calculated under five stages (Stage 0 to 4).

The details of each stage (cultivation/plantation, raw material production, pulping and transportation) are shown follows:

Stage 0 is the system for cultivation of sugar cane and plantation of eucalyptus tree in Thailand and Western Australia respectively.

Stage 1 is the system for transportation of the raw materials to the mill and pretreatment them by de-pithing from bagasse and chipping of eucalyptus in Australia.

Stage 2 is the system for local transport of eucalyptus chips in Australia, ocean transport of eucalyptus chips from Australia to Japan and local transport from ocean port to pulp mill in Japan.

Stage 3 is the system for pulping of bagasse in Thailand and eucalyptus chips in Japanese pulp mill.

Stage 4 is the system for local transport of bagasse pulp in Thailand, ocean transport from Thailand to Japan and local transport in Japan.

A measure of LCI is determined by amount of CO_2 absorption and emission associated with the stage 0 to 4.

The production process of bagasse pulp consists of the following facilities, which is shown just as reference.

Bagasse Wet Storage System

- ✓ Soda Cooking Process
- ✓ ECF (Elemental Chlorine Free) Bleaching
- ✓ Fully Chemical Recovery System (include a recovery boiler)
- ✓ Power Plant with 20 MW Turbine Generator and 3.5 MW Motor Generator
- ✓ Two Coal Fire Power Boilers with Electrostatic Precipitators
- ✓ Waste Water Treatment System with Methane Gas Generation System
- ✓ Fully Distribution Control System

On the other hand, eucalyptus pulp is manufactured by the conventional sulfate process and its operating data is available from literatures[4~5, 18].

Fig.2 illustrates the flow diagram for criteria to analyze the LCI of bagasse and eucalyptus pulp. Details of Fig.2 are discussed in the following clauses.

2-4. Comparison between cultivation of sugar cane and plantation of eucalyptus

First of all, it is necessary to calculate the amount of biomass resources for pulp production of 100,000 Bdmt per year each and the amount of fertilizer and herbicide and the fuel of agricultural implement to cultivate sugar cane and to plant eucalyptus tree.

Table 1 shows the principal conditions for comparison between cultivation of sugar cane and plantation of eucalyptus tree.

The required amounts of both biomass resources to produce the pulps of 100,000 Bdmt per year each are calculated as 4,098,361 Bdmt per year for sugar cane whereas 200,000 Bdmt per year for eucalyptus tree. The areas for cultivation or plantation of the resources are 61,170 ha for sugar cane and 18,182 ha for eucalyptus tree, respectively. The basic data for calculation are shown as remarks.

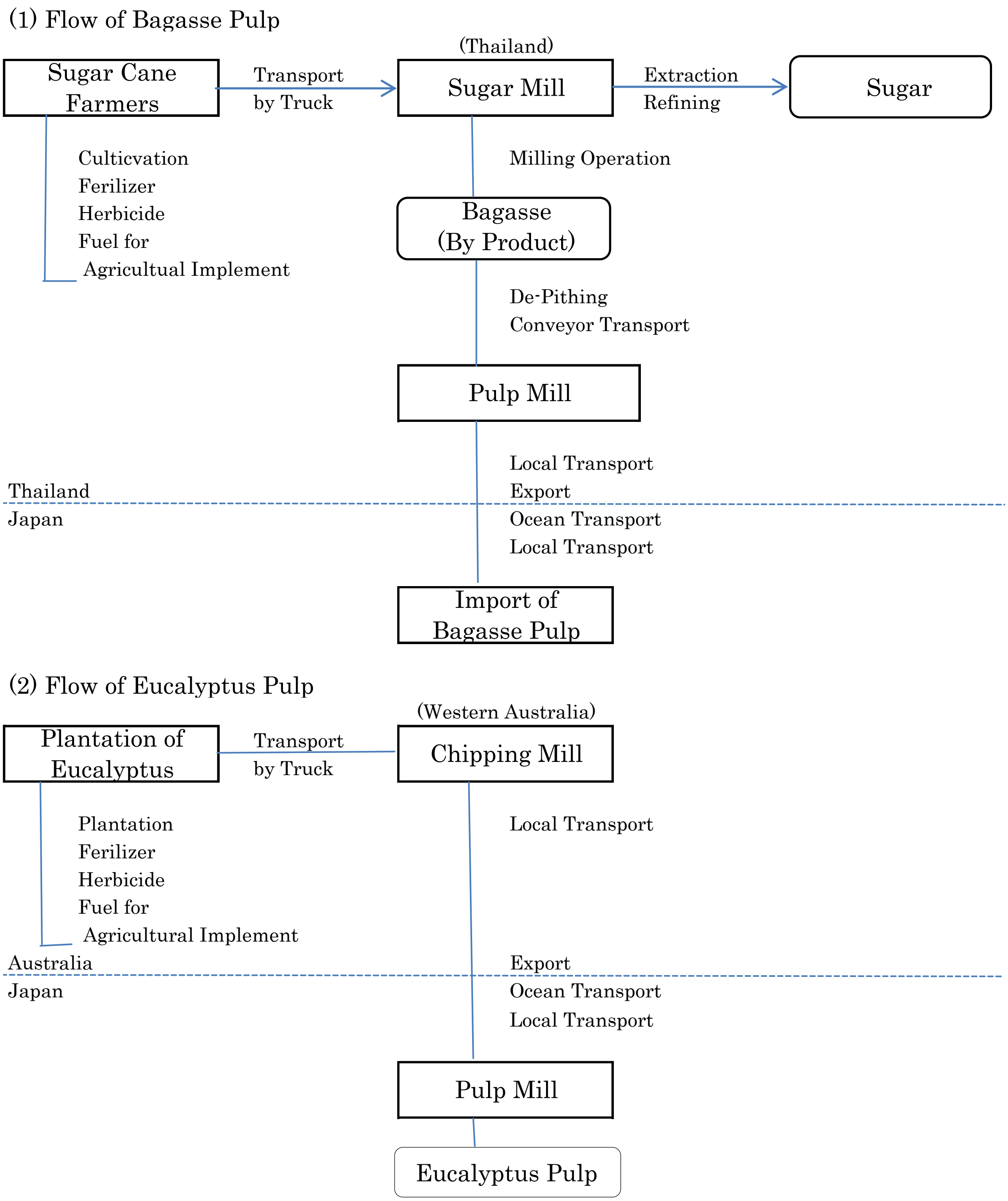

Fig.2 Criteria to calculate LCI of Two Pulps

Table 1 Comparison between Cultivation of Sugar Canes to Plantation of Eucalyptus

Cultivation of Sugar Canes	
①	Production amounto of Bagasse Pulp: 100,000 Bdmt/y (300 Bdmt/d × 333 days)
②	Yield fo Pulping is 40% (Yield of depithing Cooking, Cleaning, Bleaching and Sheetmaking)
③	Total amount of Bagasse: 250,000 Bdmt/y
④	Balance of Sugar Cane and Bagasse:286t of Bagasse is discharged from 1,000t of Sugar Canes and 61t of them is consumed for Pulp Production
⑤	61t of Bagasse for Pulp corresponds to 1,000t of Sugar Canes
⑥	Amount of Suagr Canes required: 4,098,361Bdmnt
⑦	Growing rate of Sugar Cane is 67t/ha, 73% Water Content (in 7 months) and is 18.1Bdmt/ha
⑧	Cultivation area required for the project: 61,170ha
⑨	Consumption of fertilizer is 194t
⑩	Consumption of herbicide is 3.4t
⑪	Consumption of light Oil is 5.821L

Plantation of Eucalyptus	
①	Production amount of Eucalyptus Pulp 100,000 Bdmt/y (300 Bdmt/d × 333 days)
②	Yield of Pulping is 50% (Yield of Chipping, Cooking, Cleaning, Bleaching and Sheetmaking)
③	Total amount of Eucalyptus: 200,000 Bdmt/y
④	Growing rate of Eucalyptus is 11.Bdmt/ha/y
⑤	Planting area required is 18,182ha
⑥	Consumption of fertilizer for planting is 400t
⑦	Consumption of herbicide is 16.4t
⑧	Consumption of Light weight oil is 23,273L

Remarks;

Bagasse Pulp	
②	0.8 × 0.53 × 0.955 × 0.99
③	100,00t ÷0.400
④	See Reference 13
⑥	250,000t × 1,000/61
⑦	See Reference 20、67 × (1-0.73)
⑧	4,098,361t ÷67.0 =61,170ha
⑨	61,170ha × 52kg/ha × 61/1,000
⑩	61,170ha 0.9kg/ha × 61/1,000
⑪	61,170ha × 1.56L/ha × 61/1,000

Eucalyptus Pulp	
②	0.97 × 0.545 × 0.965 × 0.99
③	100,000t/y ÷0.50
④	See Reference 12
⑤	200,000t ÷11.0t/ha
⑥	18,182ha × 22kg/ha
⑦	18,182ha × 0.9kg/ha
⑧	18,182ha × 1.28L/ha

2-5. Comparison of CO_2 absorption between sugar cane and eucalyptus in growing stage.

Amounts of CO_2 absorption of both resources are calculated by multiplying growing rate of sugar cane and eucalyptus by a factor of 147 gCO_2/100g-biomass. The reference concerning with relation to photosynthetic and biomass production is given by the published paper [11&17)]. Growing rate for sugar cane and eucalyptus tree are 18.1Bdmt/ha and 11.0Bdmt/ha, respectively.

Table 2 shows the comparison between CO_2 absorption by cultivation area of sugar cane and plantation area of eucalyptus. Basic calculation data are shown in the remarks.

2-6. De-pithing of bagasse and chipping of eucalyptus tree.

Bagasse typically contains about 40% fibers, 25% pith (parenchyma cells) and about 35% vessels. The major obstacle to bagasse pulping is the high pith content in the bagasse, which represents about 25% by weight of bagasse. Pith cells are worthless for papermaking and consume more chemicals during pulping. Pith cell are best removed mechanically before pulping process. This process can be expedited by the controlled partial fermentation of bagasse in storage prior to the de-pithing operation.

Table 2 Comparison between CO_2 Absorption of Sugar Cane & Eucalyptus in Growing Stage

Cultivation of Sugar Canes		Plantation of Eucalyptus	
①	Amount of CO_2 Absorption to Sugar cane Unit per year is calculated by a Factor ×Growing Rate 26.607tCO_2	①	Amount of CO_2 Absorption to Eucalyotus Unit per year is calculated by a Factor ×Growing Rate 16.2tCO_2
②	Total amount of CO_2 Absorption in Sugar Canes is 2,385,738tCO_2	②	Total amount of CO_2 Absorption in Eucalyptus is 294,548tCO_2
③	Amount of CO_2 Absorption in 3 items; Sugar 6662,795tCO_2 Bagasse for Fuel 1,355,534tCO_2 Bagasse for Pulp 367,500tCO_2 Total 2,385,738tCO_2		

Remarks

Sugar Canes		Eucalyptus	
①	See reference 17, 18.1t/ha × 147g/100g	①	See Reference 17, 11.0t/ha × 147t/ha × 100g
②	Total amount of Sugar Canes required; 250,000t ×1,000t/61t = 4,098,361t Total Sugar Canes for each item; Suagr 4,098,361t ×110/1,000t = 450,820t Bagasse for Fuel 4,098,361t ×225t/1,000t = 922,131t Bagasse for Pulp 4,098,361t ×61t/1,0007 = 250,000t Total = 1,622,951t CO_2 Absorption 1,622,951t ×147/100 = 2,385,738t	②	18,182ha × 16.2t/ha
③	CO_2 Absorption for each item; Sugar 450,820t ×147/100 = 662,705t Bagasse for Fuel 922,131t ×147/100 = 1,355,533t Bagasse for Pulp 250,000t ×147/110 = 367,500t Total 2,385,738t		

Table 3 shows an outline of de-pithing of bagasse and chipping of eucalyptus tree.

It is known that the power consumption to remove pith cell from bagasse is 6,250,000 kwh, whereas 6,100,000 kwh for chipping of eucalyptus tree. A detailed explanation to de-pithing and chipping are referenced by remarks.

2-7.Transportations of bagasse pulp and ecalyptus chip

Table 4 shows the analytical data of transportation of bagasse pulp and eucalyptus chip. Bagasse pulp is transported from the pulp mill to ocean port in Thailand and then exported to Japan by container carrier. Eucalyptus chip is also transported from chip mill to ocean harbor in Western Australia and exported to chip yard of pulp mill in Japan in bulk.

The each conditions of transportation are estimated by several data and the fuel consumptions for the transportation are calculated as shown in Table 4.

Here, remarks are fundamental reference data to calculate the transporting expenses of bagasse pulp and eucalyptus chip.

Table 3 Comparison of De-Pithing of Sugar Cane to Chipping of Eucalyptus

De-Pithing of Sugar Cane		Chipping of Euclayptus	
①	Local Transport Distance for Sugar Cane from Cultivation Area to Sugar Mill 24km	①	Local Transport Distance for Eucalyptus from Plantation Area to Chipping Mill 80km
②	Pith Content is 25%. Pith is almost removed by de-pithing at Pulp Mill	②	Amount of Eucalyptus Chip; 200,000Bdmt
③	Amount of Bagasse required ; 250,000 Bdmt	③	Amount of Fuel consumption for Chipping; 451,200L
④	De-Pithing Rate is 20% and is 50,000t	④	Yield f Chippng; 96%
⑤	Electric power of 6,250,000kwh is required for de-pithing	⑤	Power Consumption for Chipping; 6,100,000kwh
⑥	Bagasse is sent by conveyor from Sugar Mill to Pulp Mill		
⑦	Power Consumption by Conveyor; 25,000kwh		

Remakrs;

Sugar Cane		Eucalytous	
①	Estimated	①	See Reference 18
③	100,000t÷0.40	②	100,000t ÷0.50
④	250,000Bdmt × 20%	③	See Reference 15, 18
⑤	250,000Bdmt × 25.0kwh/Bdmt	⑤	200,000Bdmt × 30.5kwh/Bdmt
⑦	250,000Bdmt × 0.1kwh/Bdmt		

Table 4 Comparison between Transportation for Bagasse Pulp and Eucalyptus Chip

Bagasse		Eucalyptus Chip	
①	Local Transport from Pulp Mill to Ocean Port in Thailand; 200km	①	Local Transport from Chip Mill to Ocean Port in Western Australia; 80km
②	Fuel Consumption of 20Ft Container truck; 0.543L/km	②	Capacity of 15t Truck; 21.8m^3
		③	Chip Weight to Volume; 0.455t/m^3 Chip Volume to Weight; 2.2m^3/t
③	Loading weight of 20Ft Container truck; 17.6t (200kg/bale ×80 bales)	④	Loading Weight of 15t Truck; 9.92t
④	Fuel Consumption Unit; 0.0309L/km/t	⑤	Fuel Consumption of Truck; 0.37L/km
⑤	Fuel Consumption of Land Transport; 618,000L	⑥	Fuel Consumption Unit; 0.0373L/km
⑥	Ocean Transport Distance from Thailand to Japan; 6,000km	⑦	Total Weight of Chip; 200,000Bdmt
⑦	Volume of Baled Pulp; 1.54m^3/t	⑧	Total Fuel Consumption of Land Transport; 596,800L
⑧	Fuel Consumption unit of Ocean Transport; 2.33g/km/t	⑨	Transport Distance from Western Australia to japan; 13,000km
⑨	Total weight of Pulp; 100,000t	⑩	Chip Volume to Weight; 2.2m^3/t
⑩	Fuel Consumption of Ocean Transport; 1,398t	⑪	Fuel Consumption Unit of Ocean Trasnport; 3.33g/km
⑪	Density of heavy Oil; 0.95t/kL		
⑫	Total Consumption of Heavy Oil in Ocean Transport; 1,472kL	⑫	Total Fuel Consumtpion of Ocean Transport; 8,658t
		⑬	Density of heavy Oil; 0.95t/kL
		⑭	Total Consumption of Heavy Oil; 9,114kL

Remarks

Bagasse Pulp

①～④ See Reference 18 (Estimated)

⑤ 0.0309L/km·t × 200km × 100,000t

⑥～⑧ See Reference 18, 19

⑦ Bale Size of Bagasse Pulp;
0.7m × 0.8m × 0.55m, Volume = 0.308m3,
Dry weight = 200kg/bale,
0.308m3 / 200kg = 1.54m3/t

⑧ Calculated by using Unit of 3.33g/km/t (Eucalyptus) and Unit for Bagasse is obatined according to m^3/t
3.33g/km/t ×1.54/2.20 = 2.33g/km/t

⑩ 2.33g/km/t ×6,000km × 100,000t

⑫ 1,398 ÷0.95t/kL

Eucalyptus Chip

①～⑤ See Reference 18

⑥ 0.37L/km÷9.92t

⑧ 0.0373L/km/t × 80km × 200,000t

⑪ 1,000t / 13,000km/25,000t

⑫ 3.33g/km/t × 13,000km × 200,000t

⑭ 8,658t÷0.95t/L

2-8. Comparison between pulping conditions for cooking of bagasse and eucalyptus

To proceed with the LCI evaluation on pulping processes of bagasse and eucalyptus, it is essential to obtain much information on chemical consumption of cooking, production of steam by recovery boiler and pulping yield, and so on, for bagasse and eucalyptus pulp production. These data is collected and analyzed from reference material. Detail data is deleted in this paper and typical figure for yield of de-pithing, cooking, bleaching, cleaning and pulp sheetmaking is shown in Fig. 3.

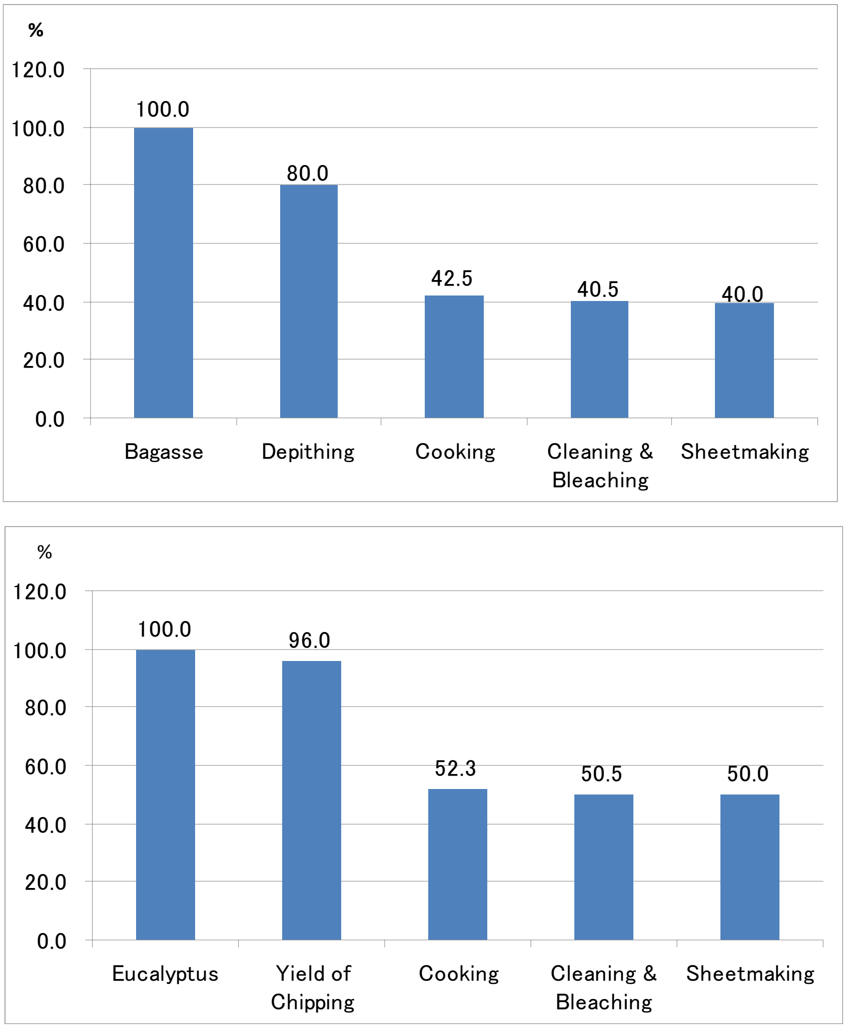

Fig.3 Pulp Yield in Pulping Process on Bagasse and Eucalyptus

3.　Results and discussion

Non-wood plant fibers, such as straw, bamboo, reed, jute, bagasse, etc, have been regarded as another option for securing the raw materials for papermaking for the future that would reduce dependence on wood. Among these non-wood plant fibers, bagasse pulp seems to be a potential alternative of wood because about 13 billion (wet) metric tons of sugar cane has been planted worldwide annually and about 30% of them are disposed as the residue, i.e.bagasse, from the production of cane sugar. Most of them are burnt as fuel.

Recently, however, some have been interested as utilization of biomass resources such as a feedstock for pulp and paper production or bio-fuel materials. In Thailand, about 60 million (wet) metric tons sugar cane has been cultivated and almost 17million (wet) metric tons of bagasse had been released. Kaset Thai Sugar Co. is the largest one of Thailand and EPPCO lies adjacent to its sugar mill. That is to say, EPPCO may be an idealistic industrial waste treatment plant from point of view of “sweet remains” .

To determine the possibility of the use of bagasse pulp as the alternative resources for the packaging materials on the view point of global environment, a Life Cycle CO_2 analysis was conducted.

LCI analysis of bagasse pulp and eucalyptus pulp as a cellulosic packaging material can be completed by introduction of the figures shown in the Tables 1 to 4 and the Fig.2 to 4. The following Table 5 was prepared to clarify the factors for the emission and absorption of CO_2 for related items.

Table 5 Factor Table for CO_2 Emission and Absorption on the related items

Emission			Absorption		
Item	Unit	Factor	Item	Unit	Factor
Fertilizer	t/t	0.97	Sugar Cane	t/ha	26.6
Herbicide	t/t	7.65	Eucalyptus	t/ha	16.2
Light Oil	kg/L	2.49			
Electric Power	kg/kwh	0.44			
Black Liquor	kg/kg	1.15			
Supplementary Steam	kg/kg	0.27			
Heavy Oil	kg/L	2.87			

A comprehensive summary of CO_2 emission and absorption of both pulps is shown in Table 6, which was also completed by introduction of the figures and data shown in Tables 1 to 5 and Figures 1 and 2.

As shown in the Table 6, total CO_2 emission of bagasse pulp is 165,209 tCO_2 while CO_2 emission by eucalyptus pulp is 185,216 tCO_2. Total CO_2 absorption of bagasse pulp is 367,500 tCO_2, while CO_2 absorption of eucalyptus pulp is 294,548 tCO_2.

Also as shown in the Table 6, the balance of CO_2 emission and absorption of bagasse pulp is 202,291 tCO_2 absorption and that of eucalyptus pulp is 109,332 tCO_2 absorption.

In the case of eucalyptus chip, about 200,000 Bdmt is transported for the distance of 13,000 km from Australia to Japan, which results CO_2 emission of 26,157 tCO_2. In the case of bagasse pulp, 100,000 Bdmt is transported for 6,000 km from Thailand to Japan. Then, CO_2 emission of bagasse pulp for ocean transportation is only 4,225 tCO_2, which is 1/6 of that of eucalyptus pulp, though there will be some differences in the pulping processes.

Table 6 Summary CO_2 Emission and Absorption of Bagasse Pulp and Eucalyptus Pulp

	Stage	Item	Bagasse Pulp (Unit:tCO_2)	Eucalyptus Pulp (Unit:tCO_2)
CO_2 Emission	0	Growing Process	228	571
	1 Pre/ Processing	Local Transport De-pithing Chipping	11 2,759 	1,123 2,684
	2 Chipping	Local Transport (Australia) Ocean Transport Local Transport (Japan)		1,486 26,157 516
	3 Pulping	Consumption of Black Liquor Supplementary Steam	135,104 21,147	104,775 47,904
	4 Pulp	Local Transport (Thailand) Ocean Trasnport Local Transport (Japan)	1,539 4,225 196	
	Total Emission		165,209	185,216

4. Conclusion

A LCI analysis on the bagasse pulp produced in Thailand and the eucalyptus pulp originated from Western Australia that are assumed to be used in Japan as a cellulosic packaging materials.

It is demonstrated that total CO_2 emission is 165,209 tCO_2 per year for bagasse pulp while 185,216 tCO_2 per year for eucalyptus pulp in order to provide furnish as packaging materials. The amount of CO_2 absorption is 367,500 tCO_2 per year for bagasse pulp while 294,548 tCO_2 per year for eucalyptus pulp.

These results suggest that the use of bagasse pulp, a non-wood biomass resource, as the packaging material has a potential to contribute the reduction of the greenhouse gas emission.

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紙系包装材料としてのバガスパルプの LCI 分析

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各種容器･包装のカーボンフットプリントを求めるにあたって、主要な包装材料であるセルロース繊維系材料の CO_2 吸収・排出量を把握することが必要になってくる。そこで本研究では、セルロース繊維系包装材料という観点から、２つの製紙原料、すなわちバガスパルプとユーカリパルプの LCI 分析を行なった。

バガスは、熱帯および亜熱帯地域で栽培されたサトウキビから砂糖を採取した後の残渣で、地球温暖化防止に対応した 21 世紀のセルロース繊維系資源として注目されている。2003 年よりタイでは、製糖工場に隣接して 100,000Bdmt (Bone dry metric ton)/年のバガスパルプ工場が生産を開始し、さらにバガスパルプを用いた食品用パルプモールド工場などが稼動し、わが国にも輸出されている。一方、以前より輸入製紙原料の一つとして、西オーストラリアで植林されているユーカリ材のチップがわが国に輸入され、製紙用パルプとして大量に用いられている。両者のパルプ生産量を 100,000 Bdmt/年として、５つの工程（パルプ生産に必要な植物資源の生産、植生による吸放出、パルプ工場への原料輸送, パルプ製造工程、中間製品の現地から日本へ輸送）について、CO_2 排出量を LCI 分析した。

その結果、CO_2 放出量はバガスパルプでは 165,209tCO_2/年に対し、ユーカリパルプでは 185,216 tCO_2/年となった。また、CO_2 吸収量はバガスパルプでは 367,500tCO_2/年に対しユーカリパルプでは 294,548tCO_2/年となった。これらの結果から、バガスパルプの利用による温室効果ガス削減の可能性が示された。

キーワード：LCI、バガスパルプ、ユーカリパルプ、包装材料、栽培、加工、輸送、CO_2,　カーボンフットプリント