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WFP SSTC Field Pilot Project in the Republic of Congo supported by China

Advances in Banana Processing Technologies and Products

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Cloud School
Sharing for Learning

Expert's Profile

Mr. Wei ZHOU

- **Education Degree**: Ph.D.
- **Academic Title**: Director of Food Processing Laboratory, Associate Researcher
- **Specialism**: Excavation and Exploitation of Functional Factors of Tropical Characteristic Food

CONTENTS

Banana Production

- Bananas are monocotyledons and belonging to the Musaceae family and cultivated primarily for fruit.
- The earliest reference to banana dates back to about 500 BC. Some horticulturists suspected that banana was the earth's first fruit.
- Banana is reported to be the fourth most demanded food after rice, wheat and corn.
- As many as 100 million people subsist on bananas as their staple food and main energy source.

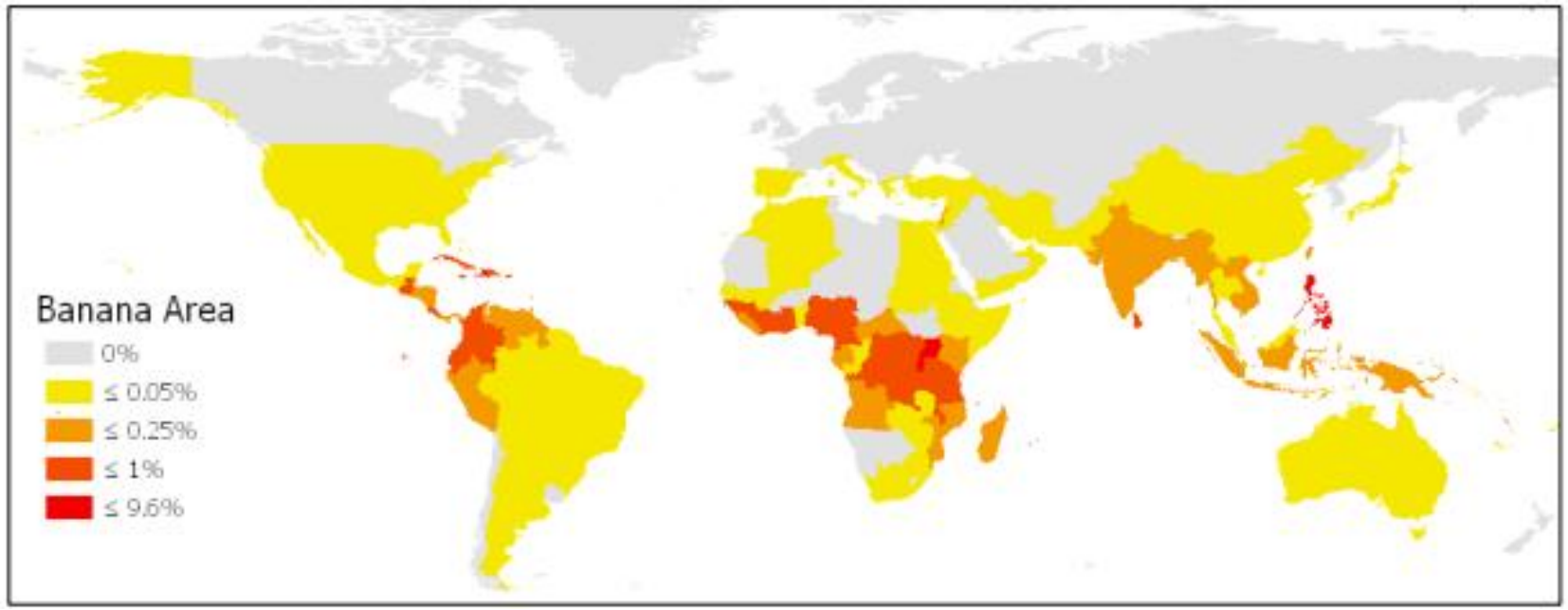


Figure. Percentage of banana production in different continents in world production(date source: FAOSTAT, 2020)

- Bananas originated mainly in Southeast Asia and the Western Pacific, gradually spread throughout tropics and subtropics.
- Banana is the second largest produced fruit, contributing about 16% of the world's total fruit production.
- India is the largest producer of bananas (32.0 million metric tons, 2020), large banana producing countries are mostly African countries (1.74 million hectares, 2020).

Table. Banana production of major producing countries in Latin America (FAO, 2020)

Country	Production/metric tons
Equador	7,931,060
Brazil	6,978,310
Guatemala	2,621,500
Mexico	2,103,360
Colombia	2,034,340
Peru	2,007,280

Table. Banana production of major producing countries in Asia (FAO, 2020)

Country	Production/metric tons
India	31,897,900
China	9,848,895
Indonesia	5,814,580
Philippines	1,101,340

Table. Banana production of major producing countries in Africa (FAO, 2020)

Country	Production/metric tons
Uganda	9,550,000
Ghana	3,537,730
Tanzania	2,924,700
Rwanda	2,749,150
Nigeria	2,733,300
Cameroon	2,604,100
Cote d'Ivoire	1,600,000
Congo	1,250,690
Kenya	791,579

- More than 1000 varieties of bananas produced and consumed in the world.
- Banana consists of two genera *Musa* Linnaeus. and *Ensete* Bruce. Almost all the edible cultivated bananas are derived from genus *Musa*.
- Three common species of *Musa* are *Musa cavendishii*, *Musa paradisiaca*, and *Musa sapientum*.

Musa cavendishii

Musa sapientum

- *M. cavendishii*, known as dessert banana, is sweeter and less starchy.
- *M. paradisiaca* and *M. sapientum* are cooking bananas, characterized by higher starch concentration.

Banana Nutrition

First choice for athletes' energy supply: two bananas provide energy for 90 minutes of workout

Best sources of potassium: one banana fulfils 8% of the daily recommended value

Low glycemic index (GI): resistant starch and non-starch polysaccharides

Rich in polyunsaturated fatty acids: linoleic acid and α-linolenic acid

Table. Pulp and peel composition (fresh weight basis) of dessert bananas (AAA and AAB variety)

Composition	Pulp		Peel
	AAA	AAB	
Moisture, %	73.8±0.5	68.5±0.6	83.5
Vitamin A, μgRAE/100g	8.2±0.6	12.4±1.0	-
β-carotene, μg/100g	55.68±14.1	96.87±30.7	-
Vitamin C, mg/100g	4.5±0.3	12.7±0.7	-
Soluble solids, °Brix	20.5±0.4	17.9±0.7	-
Proteins, %	2.2	-	1.8
Fat*, %	0.1	-	1.7*
Glucose, %	5.0	-	2.4
Fructose, %	6.5	-	6.2
Sucrose, %	12	-	2.6
Maltose, %	0	-	0
Starch, %	10	-	1.2
Cellulose, %	9.1	-	8.4
Total Sugar, %	40	-	29
Potassium (K), mg/100g	318.95±28.2	342.3±67.7	78.1±6.58*
Phosphorus (P), mg/100g	21.7±2.4	26.3±2.0	
Calcium (Ca), mg/100g	4.9±1.06	7.2±1.21	19.2±0.00
Magnesium(Mg), mg/100g	30.8±4.4	39.4±5.0	
Sodium (Na), mg/100g	17.35±3.68	16.0±8.22	24.3±0.12
Iron (Fe), mg/100g	0.83±0.19	0.75±0.22	0.61±0.22
Manganese (Mn), mg/100g	0.20±0.08	0.67±0.41	76.20±00
Zinc (Zn), mg/100g	0.23±0.05	0.39±0.32	-
Copper (Cu), mg/100g	0.26±0.18	0.26±0.14	-
Boron (B), mg/100g	0.14±0.03	0.16±0.06	-
Bromine (Br), mg/100g	-	-	0.04±0.00
Rubidium (Rb), mg/100g	-	-	0.21±0.05
Stronsium (Sr), mg/100g	-	-	0.03±0.01
Zirconium (Zr), mg/100g	-	-	0.02±0.00
Niobium (Nb), mg/100g	-	-	0.02±0.00

*dry weight basis

Pharmacological Activities of Banana

- Phenolic Compounds
- Saponins
- Vitamin C
- Vitamin B
- Sterols

(1)Antioxidant Activity

(2)Anticancer Effect

(3)Antidiabetic Effect

(4)Antimicrobial Activity

(5)Wound Healing Attribute

(6)Effect on Atherosclerosis

Banana Preservation

Post-harvest Processing of Banana

Picking → Preservation → Classification → Package → Storage and Transportation → Ripening

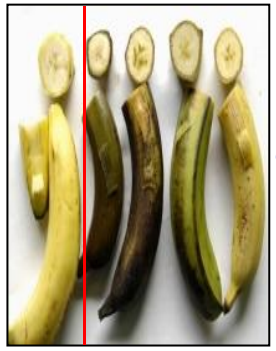
The production of bananas is subjected to serious post- harvest losses, mainly due to harvesting at improper maturity stage, poor handling and storage practices and post-harvest diseases.

Preservation Methods

- Physical Preservation Technology
- Chemical Preservation Technology
- Biological Preservation Technology

Physical Preservation Technology

● Low Temperature Preservation



- Inhibiting related enzyme activities and reducing respiration intensity
- Storage at 13~15℃ to avoid cold damage

● Modified Atmosphere Packaging

Reducing O_2 and increasing CO_2 concentration to inhibit the physiological activities of fruits and microorganisms

● Irradiation Preservation

Y-rays interfere with the basic metabolism of fruits and the growth of decaying microorganisms

● Hot Water Treatment

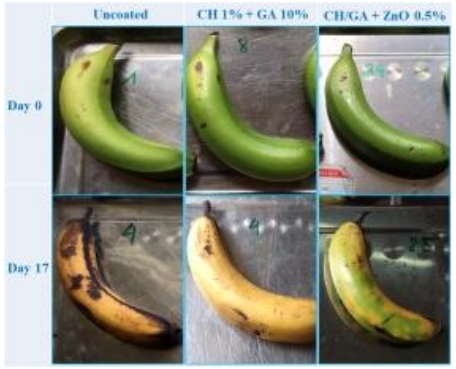
Hot water treatment of 30~55℃ reduces postharvest diseases and improves the cold tolerance of banana fruits

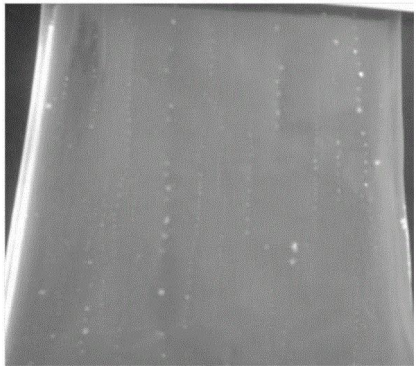
Chemical Preservation Technology

- Ethylene Antagonists and Absorbents

- Ethylene antagonists (1-MCP) binds irreversibly to ethylene receptor proteins
- Perlite or active aluminum is used to soak in saturated potassium permanganate solution as ethylene absorbent

- Edible Coatings





Polysaccharides, lipids, proteins and other natural products and their complexes commonly used as coatings

- Exogenous Plant Growth Regulators

Salicylic acid, methyl jasmonate, citric acid and oxalic acid are commonly sprayed or daubed on banana surface.

- Chemical Fungicide

Various chemical fungicides can effectively control banana rot when used alone or in combination.

Biological Preservation Technology

- Plant Extract Preservation

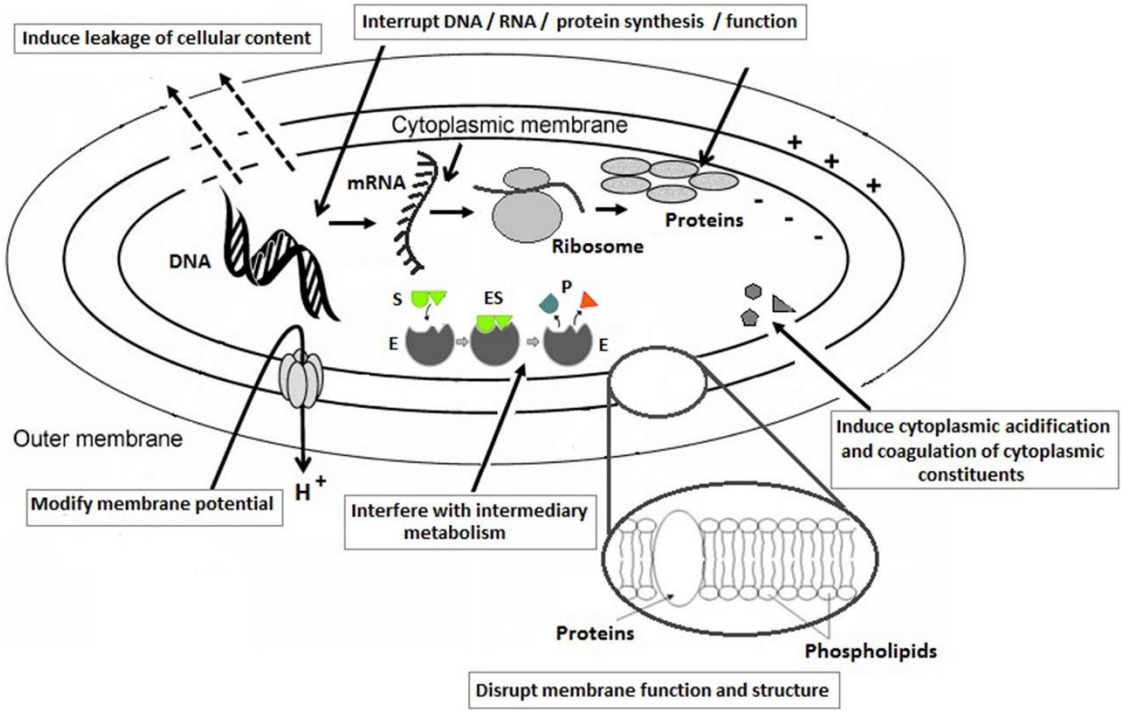
Natural plant extracts, such as plant essential oil show good antibacterial and antioxidant activities and are widely used in the preservation of banana fruits.

- Biological Enzyme Preparation Preservation

Enzyme can eliminate the adverse factors from the outside in the storage process of bananas through its catalytic effect, so as to achieve the purpose of preservation.

- Microbial Antagonism Preservation

Yeast and *Bacillus subtilis* inhibit post-harvest diseases of bananas and slow down decay by means of nutrition and space competition and producing antibacterial substances.



Banana Preservation Technology		Storage Period
Physical Preservation Technology	Low Temperature Preservation	45-50 d
	Modified Atmosphere Packaging	35- 40 d
	Irradiation Preservation	Optimal dose (25 krad) 25-30 d
	Hot Water Treatment	20-25 d
Chemical Preservation Technology	Ethylene Antagonists And Absorbents	0.5μL/L 1-MCP treatment (40-45 d) Ethylene absorbent treatment (30-35 d)
	Chemical Fungicide	20-25 d
	Edible Coatings	30-35 d
	Exogenous Plant Growth Regulators	30-35d Eg: 50 mg/L gibberellin treatment (30d)
Biological Preservation Technology	Plant Extract Preservation	20-25 d Eg: 15 μL/L Peppermint essential oil (25 d)
	Microbial Antagonism Preservation	20-25 d Eg: Pichia kluyveri (B1) (25 d)
	Biological Enzyme Preparation Preservation	20-25 d

High Quality Banana Preservation Technology

Low temperature preservation combined with controlled atmosphere storage

Storage life can exceed two months

Good fruit appearance and inner quality

Guangxi Jinsui Agricultural Group

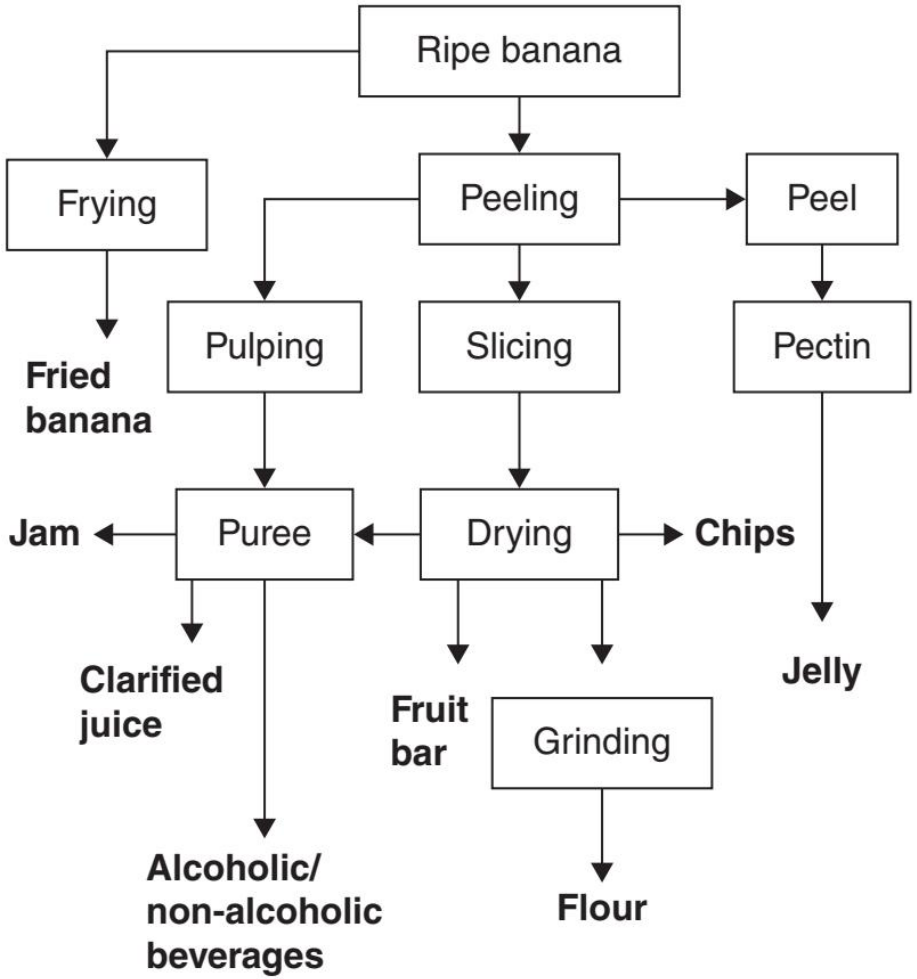
QUALITY FRUIT
佳农
Goodfarmer
SINCE 2002
FRESH EVERYDAY

Goodfarmer Foods Holding (Group)

04

Banana Processing

Comprehensive Exploitation of Bananas



香蕉果肉
Pulp

香蕉果粉及制品
Powder and its products

香蕉片
Chips

香蕉汁及制品
Juice and its products

香蕉酒
Banana wine

香蕉果酱
Banana jam

香蕉皮渣
Peels

膳食纤维
Dietary fiber

果胶
Pectin

果冻
Jelly

皮渣发酵饲料
Feed

香蕉茎叶
Stem and Leaves

造纸
Paper

纺织
Textiles

发酵饲料
Feed

- Bananas are usually consumed in fresh form. Very small portion of total banana production undergoes industrial processing.
- Fresh bananas are highly perishable, with a very little shelf life ranging from days to weeks. Product degenerates while storage and transport, causing a lot of loss of income.
- To avoid the loss of income from degeneration, bananas are encouraged to be processed into different products.

Fresh-cut Bananas
鲜食香蕉

Browning
褐变

Corruption
腐败

(a) Banana Juice

- Juice extraction is achieved by a mechanical press and/or by enzyme application.
- Juice yields of 54%–80% from peeled fruit pulp depending on the banana variety used.
- Banana juice have a moderate acidity, a very good sugar content.

(a) Banana Juice

Conventional Processing Steps and Technologies of Banana Juice

Banana Fruit
↓
Slices
↓
Extraction
↓
Fining → High Speed Centrifugation
↓
Sterilization → Pasteurization
↓
Clarified Banana Juice

(a) Banana Juice

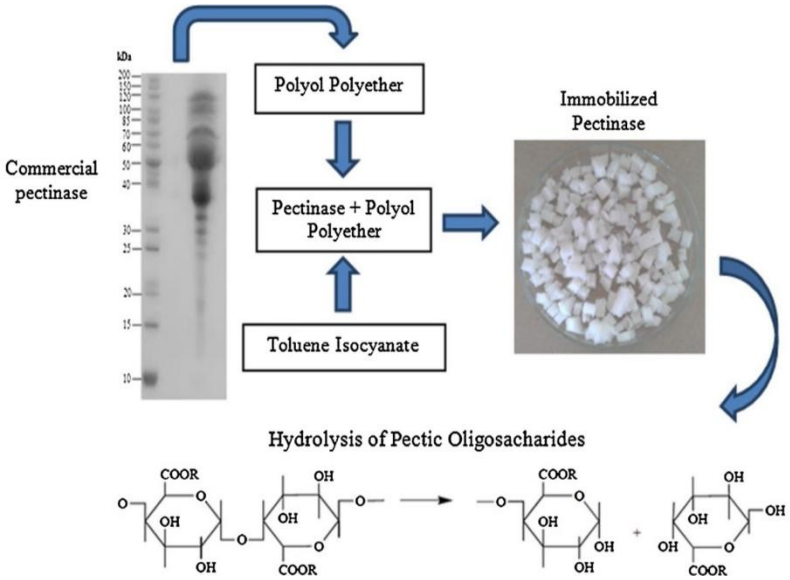
Key Technique 1: Fining

Difficult to get clear banana juice

- Reason 1: Settlement of pectins
- Reason 2: Binding between polyphenolic compounds and fining agents
- Reason 3: Bonding of proteins to form foam

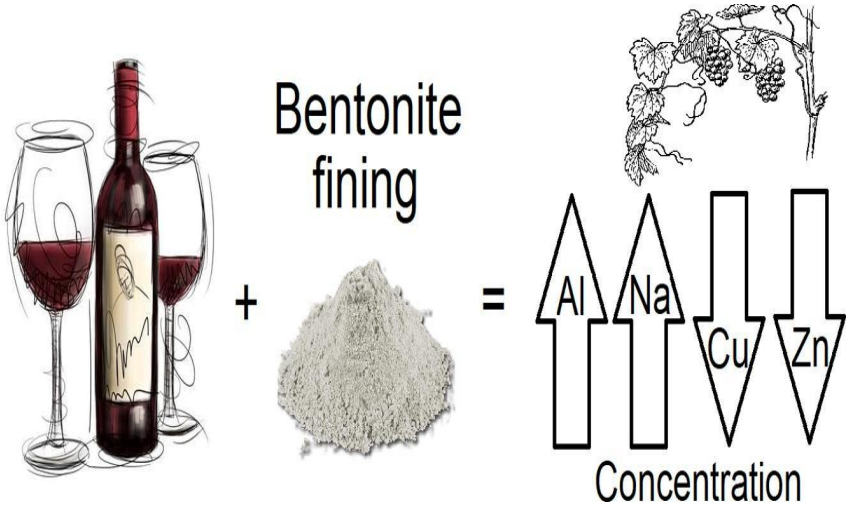
(a) Banana Juice

✓ Treatment with Enzyme



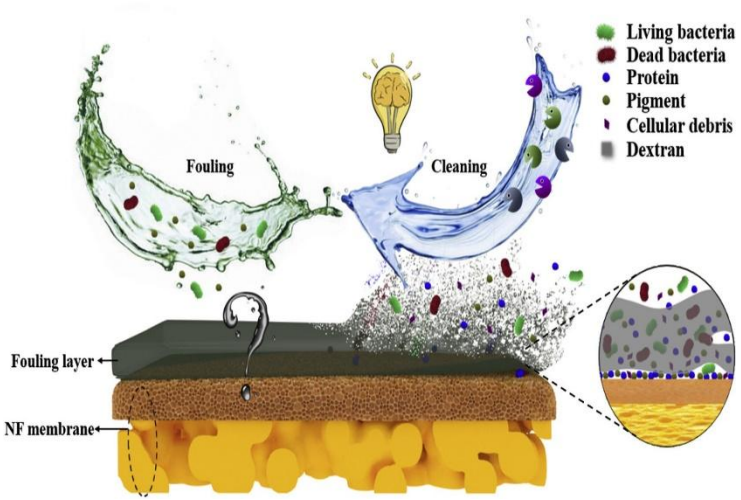
Amylase/Pectinase

✓ Fining Agents



Bentonite/Gelatine

✓ Membrane Technology



Microfiltration/Ultrafiltration/Nanofiltration/Reverse osmosis

(a) Banana Juice

Key Technique 2: Oxidation Prevention

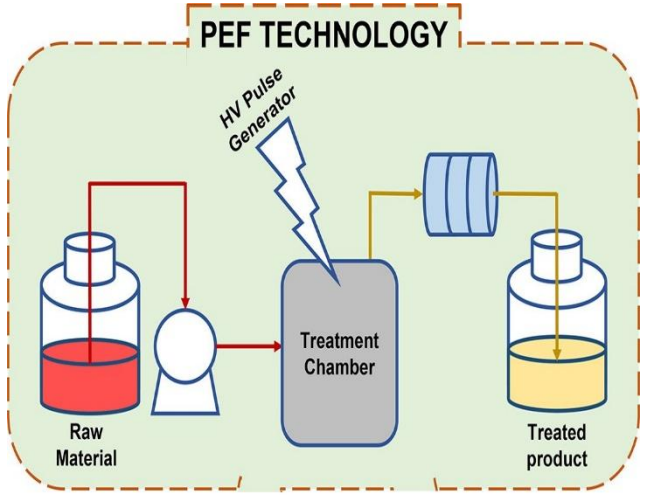
Browning and loss of ascorbic acid

- Reason 1: Polyphenol oxidase and peroxidase enzyme activity
- Reason 2: Thermal processing

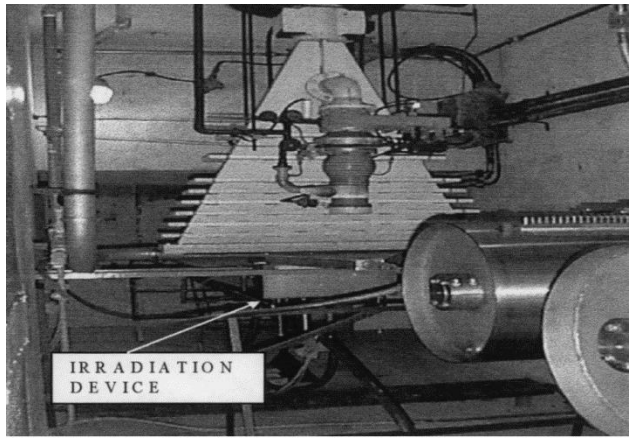
(a) Banana Juice

Non-thermal Processing Technologies

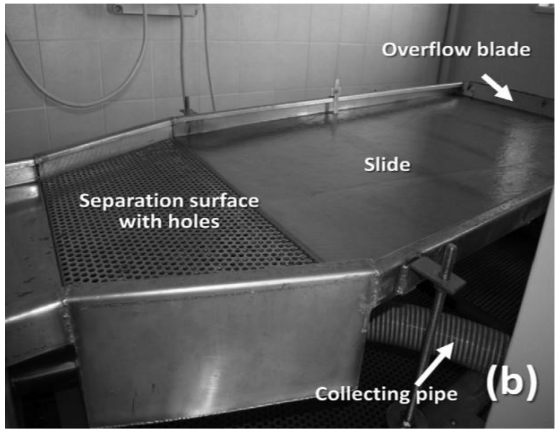
High Pressure Processing (HPP)



Pulsed Electric Fields (PEF)



Irradiation Processing



Dipping into Antioxidant Solution before Heating

Preservation of Banana Juice

Keeping Ascorbic Acid

(a) Banana Juice

北大荒集团 BEIDAHUANG GROUP

Commodity Grain Production Base

Kinana™

金穗农业集团 JINSUI AGRICULTURE GROUP

Banana Standardization Production Enterprise

Non-thermal Extraction

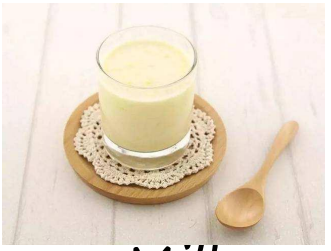
The first non-compound banana drink

Taking the lead in solving the problem of banana juice browning

(a) Banana Juice

Various Applications of Banana Juice

In combination with milk



Milk shake
奶昔

Milk power
奶粉

In combination with thickening agent

Jelly
果冻

Fudge
软糖

Fermented

Wine
酒

Vinegar
醋

(b) Banana Powder

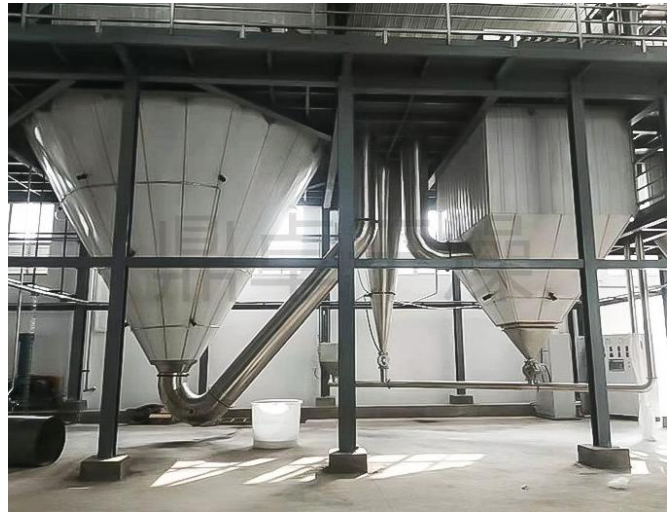
- Banana powder is actually used as an additive and ingredient in different kinds of food products.
- Banana powder is prepared from green unripe cooking bananas with high starch content.
- Banana powder possesses a very good nutritional profile.

(b) Banana Powder

Conventional Processing Steps and Technologies of Banana Powder

Banana Fruit
↓
Slices
↓
Syrup Making
↓
Mixing
↓
Drying → Spray Drying
↓
Banana Powder

Heating Effect



(b) Banana Powder

Key Technique:Drying

- Lightness and yellowness are negatively affected.
- Low emulsion stability
- Low oil and water holding capacity
- Lower content of resistant starch

(b) Banana Powder

✓ Freeze Drying

Drying

Air-oven drying:

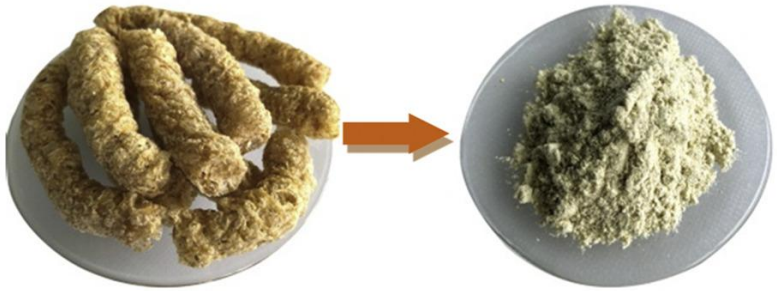
1) **ODF50** (50 °C/ 7h)
2) **ODF80** (80 °C/ 4h)
3) **ODF110** (110 °C/ 2 h)

Freeze drying:

FDF: Step one: Blast freezer (-30 °C/ 4 h)

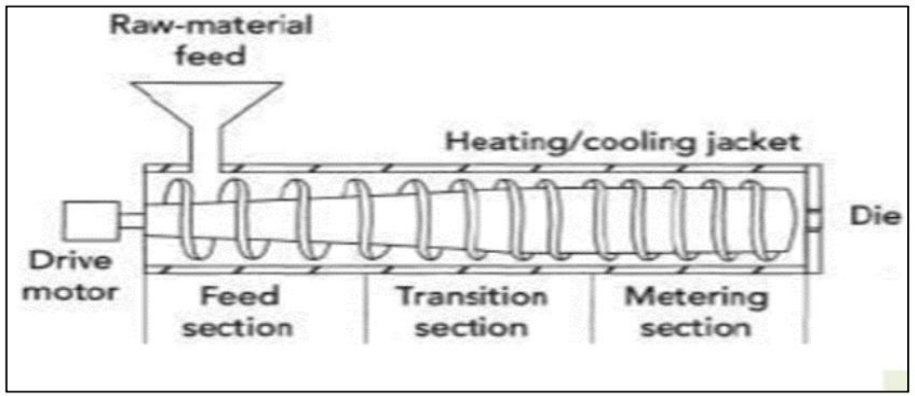
Step two: Freeze drier (10 °C/ 48 h)

Freeze drying is considered to be the best dehydration method for heat-sensitive materials.



Extrusion process
800 rpm, 40 °C

Banana flour
Solubility = 79.72 ± 1.21%



High-temperature Short-time (HTST) Process

Extrusion processing change the structure and morphology of powder more soluble in water.

(b) Banana Powder

MTD® 辽宁美同达科技有限公司
Liaoning Mutual Technology Co.,Ltd.

Freeze Drying

Australian Green Banana Powder

- High resistant starch
- Regulate blood sugar
- Regulate intestinal flora

French Diana Food

Bananas Produced in Ecuador

Extrusion Processing

- Fine particle size
- Soluble in water
- Sweet tase of ripeness

(b) Banana Powder

Various Applications of Banana Powder

From ripe bananas with high sweetness

Syrup
糖浆

Ice Cream
雪糕

From unripe bananas with high dietary fiber

Pasta
意大利面

Bread
面包

Biscuit
饼干

Noodle
面条

(c) Banana Chips

- Banana chips are a popular snack food especially in America, Europe, China, and Japan.
- Banana chip is a product with a crispy taste and golden yellow color.
- Usually, the chips are produced from under ripe bananas.

(c) Banana Chips

Conventional Processing Steps and Technologies of Banana Chips

Banana Fruit
↓
Slices
↓
Sulfer Smoking
↓
Baking/Frying
↓
Banana Chips

High Temperature Frying/Baking for a Long Time

→ Frying Machine/Oven

(c) Banana Chips

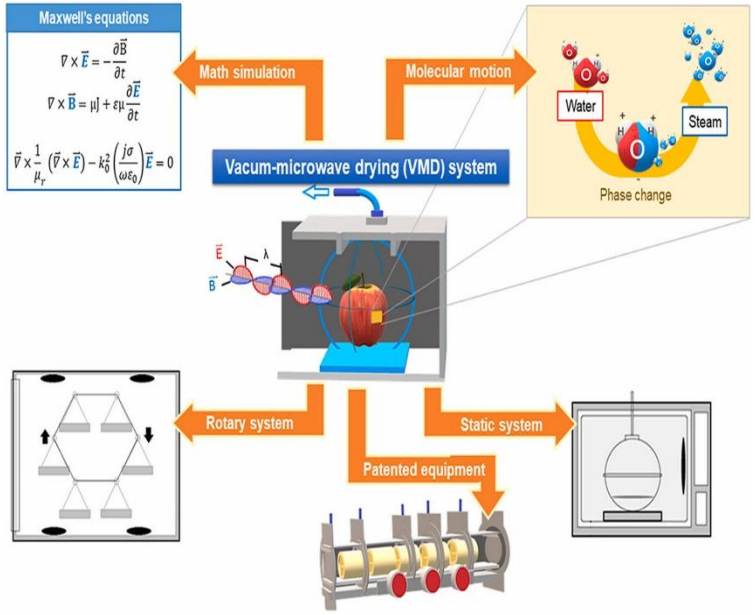
Key Technique: Oil Intake Control

- Quality of chips will deteriorate in terms of physical and chemical changes.
- Chips may not be preferred by health-conscious consumers.
- Chips may become rancid after long storage because of lipid oxidation.

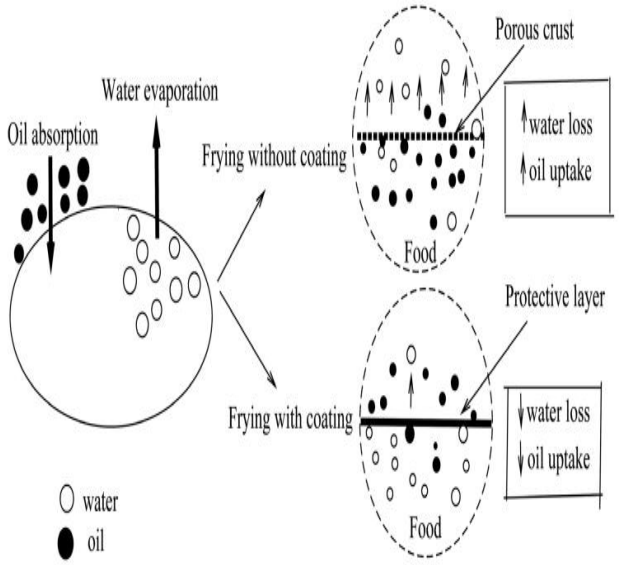
(c) Banana Chips

Methods to Control Oil Absorption

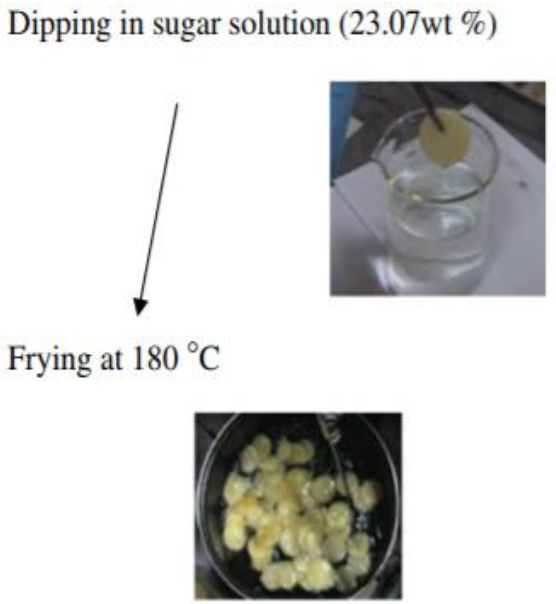
✓ Vacuum Microwave-drying ✓ Hydrocolloids ✓ Sweet Pre-treatment ✓ Osmotic Dehydration



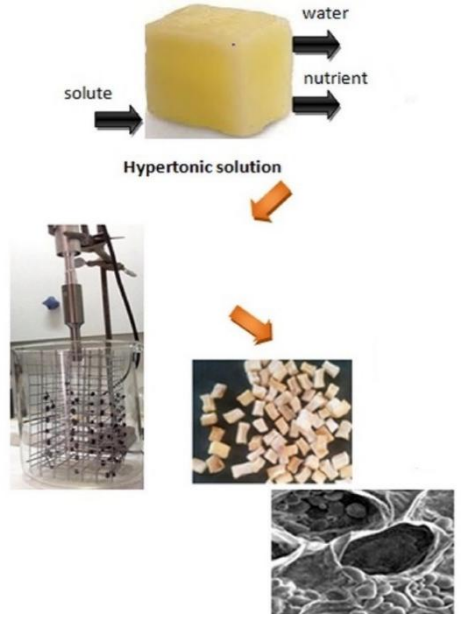
Heat penetrates materials effectively to reduce frying time.



Chips dip in alginate, CMC or pectin before frying.



Chips dip in sugar solution before frying.



Chips dip in osmotic solutions.

(c) Banana Chips

Philippine Banana Chips Processing

道吉草

Dao Ji Cao

Banana Master

Loraine Peralta

Banana chips dipped in sugar solution before frying

Quality of Product

- Thin and crispy
- Low oil and sault
- Strong banana aroma

(c) Banana Chips

Banana chips business has an important role in Indonesian economy, contributing significantly to job creation, and poverty reduction.

Cost and Profitability of Banana Chips Production in Indonesia, 2017

No	Description 类别描述	Value (IDR) 印尼卢比
1.	Cost 成本	
	Fixed Cost 固定成本	307.000
	Variable Cost 可变成本	14.190.000
	Total Cost 总成本	14.497.000
2.	Total Revenue (quantity x price) 总收入	
	720 kg x IDR 35.000	25.200.000
3.	Profit 利润	10.703.000
4.	Gross B/C	1.74
5.	Net B/C	0.74

Cost of IDR 1,000,000 banana chips business will generate revenue of IDR 1,740,000

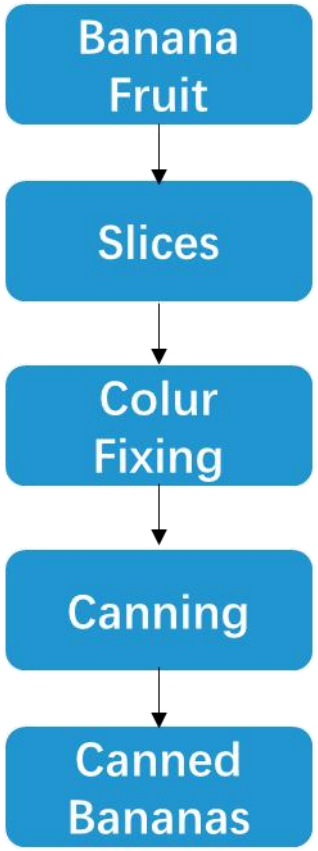
Every IDR 1,000,000 invested in banana chip business will result in a profit of IDR. 740.000

(d) Canned Banana

- Best quality canned bananas are obtained from fruit at an early stage of ripeness.
- The slices are processed in syrup of 25deg.Brix with pH about 4.2.
- Canning increases the shelf life of bananas and also help in transportation and storage.

(d) Canned Banana

Processing Steps



Key Technique: Color and Shape Preservation

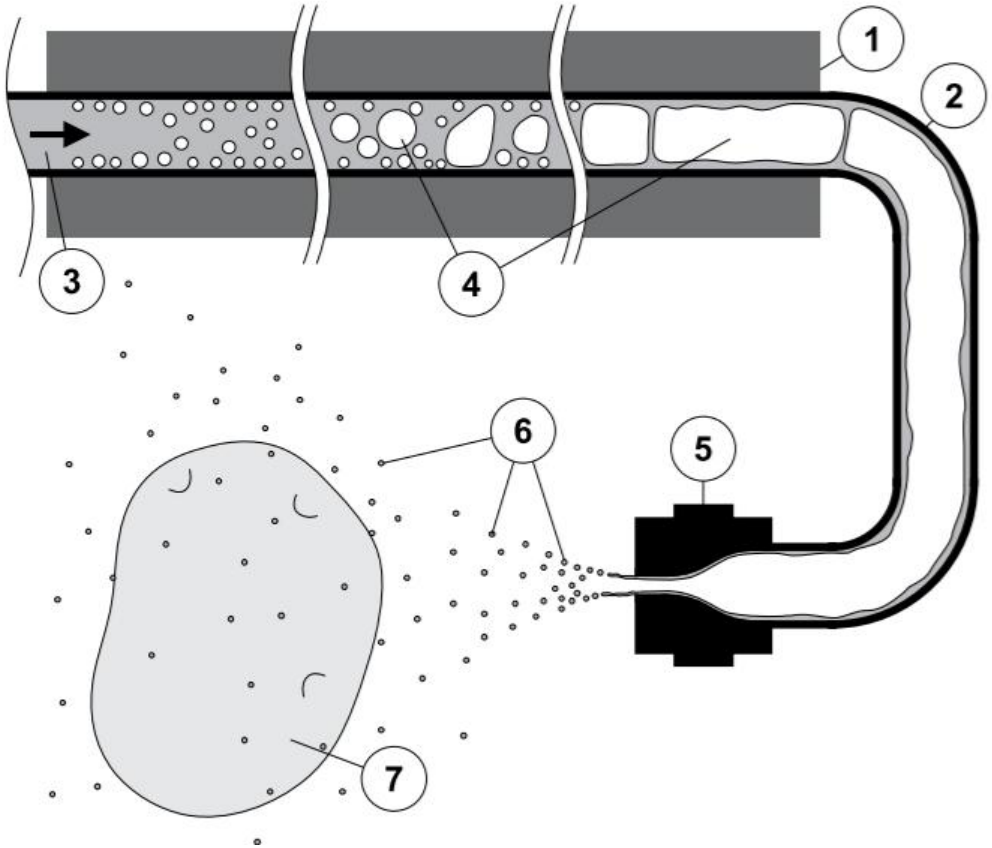
Rapid browning and difficult to ensure the proper shape and hardness of slices

- Reason 1: Polyphenol oxidase and peroxidase enzyme activity
- Reason 2: Cells damage during the peeling and slicing

(d) Canned Banana

Color Preservation

Acidic Sodium Sulphate, Citric Acid, or L-ascorbic Acid



Shape Preservation

Calcium Chloride or Calcium Lactate

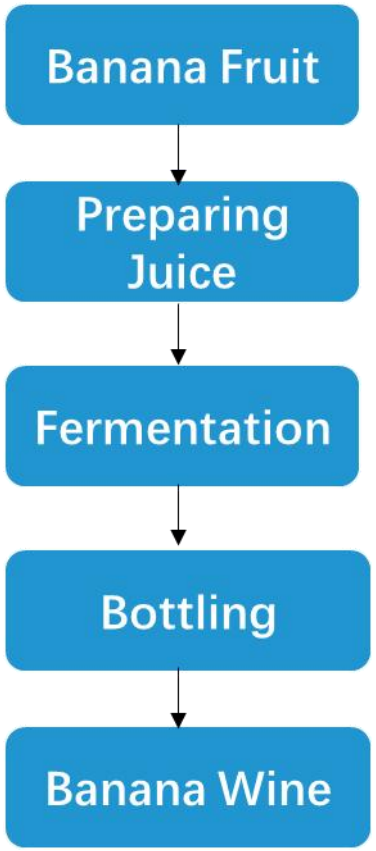
Blanching

(e) Banana Wine

- Banana fruit wine with low alcohol content is a kind of nutritious beverage, which is favored by the elderly and teenagers.
- Fermenting banana juice is considered to be an attractive means of utilizing surplus and overripe bananas.
- The cost of production of banana based alcoholic beverages is much cheaper than other fruit based beverages.

(e) Banana Wine

Conventional Processing Steps and Technologies of Banana Wine



Indigenous use of spear grass and feet to extract juice from bananas in Africa

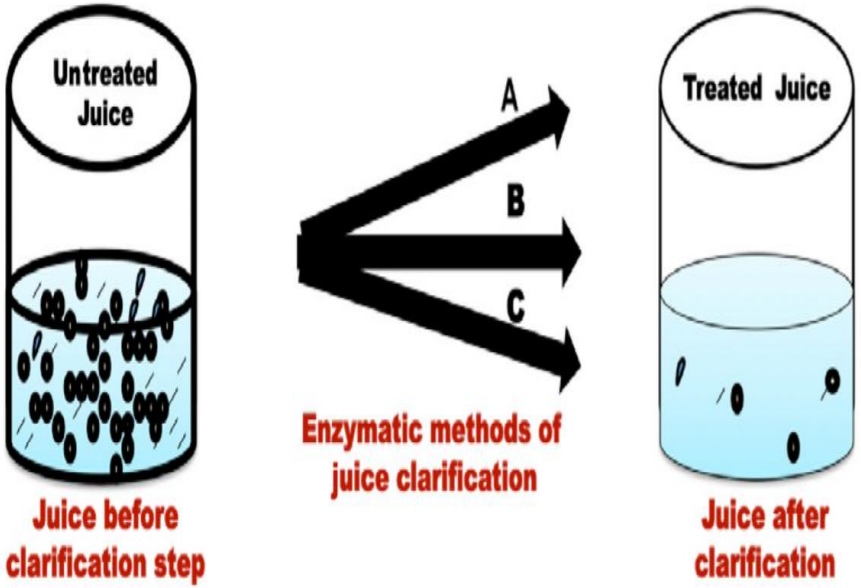
(e) Banana Wine

Key Technique:Increase Juice Yield

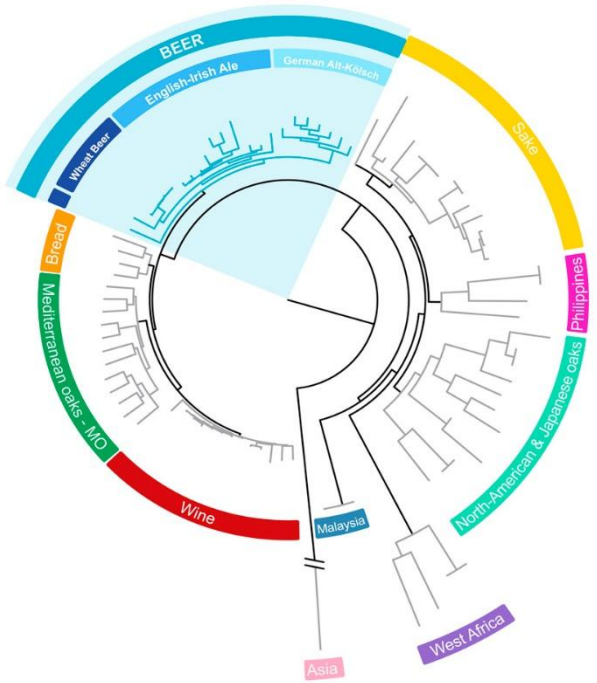
High turbidity and viscosity of banana wine

Reason: Polymeric carbohydrates like pectin and starch in banana

(e) Banana Wine



Pectinase and α-amylase were used to pretreat banana pulp before wine fermentation



Recombinant yeast strains with genes coding for enzymes able to degrade different polysaccharides

(e) Banana Wine

DE KUYPER
HOME OF THE COCKTAIL

Enzyme Treatment → Fermentation

Banana Liqueur

Guangxi Nanning lvyue Food Co., Ltd

Quality of Product

- High clarity
- Low alcohol vol
- Base for cocktail

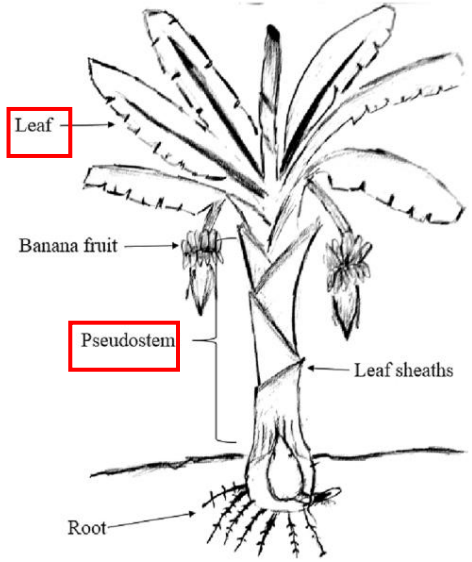
(e) Banana Wine

Banana beer processing plays an important role in the overall income generation and food security of rural communities in African countries.

Banana Beer Costs and Margins (in US$) for Retailers in African Countries

	Country		
	Rwanda	Burundi	Congo
Costs			
Buying Price (Banana Beer 16Lt)	4.00	3.21	2.98
Transport Costs	1.06	0.84	1.45
Total Variable Costs	5.06	4.06	4.44
Revenues			
Revenue (Banana Beer 16Lt)	6.84	5.38	5.53
Gross margin (Banana Beer 16Lt)	1.78	1.32	1.09

Banana Peels



Banana Leaves and Pseudo-stems

- Each hectare of banana plantation is estimated to produce biomass waste about 220 tons.
- India alone produces about 190 million tons of biomass waste from banana plantations. (Worldwide, 1.243 billion tons)
- It takes about two years to biodegrade banana waste, causing environmental problems.
- Banana waste has a good nutritional profile.

(a) Fiber

Banana Harvesting

↓

Pseudostem Cutting

↓

Separation

↓

Washing

↓

Drying

↓

Banana Fibre

- Sanitary Napkins

- ✓ Material for absorbent core and barrier sheet
- ✓ 3 to 6 months to biodegrade
- ✓ Natural, cheap and 50% higher absorption strength than cotton fibers

Saathi Health Care Company in India

100% biodegradable and chemical-free pads made of banana fiber

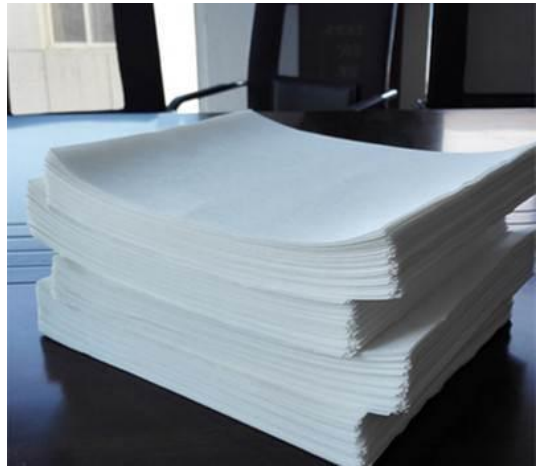
Sanfe India's Female Hygiene Brand

Pads from banana fiber with repeated usage up to 120 washes

(a) Fiber

- Banana Harvesting
- Pseudostem Cutting
- Separation
- Washing
- Drying
- Banana Fibre

Paper Industry



- ✓ Non-wood raw materials for paper production can protect forest.
- ✓ Banana fiber has the potential for paper production due to high cellulose, lower hemicellulose and lignin.
- ✓ Production of currency paper, cheque paper, writing paper and anti-grease paper
- ✓ Paper made from 100% banana fiber was found most absorbent and abrasion resistant.

☛ Japanese Yen notes are made of banana fiber.

(a) Fiber

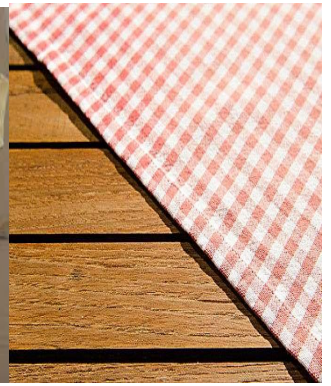
Banana Harvesting
↓
Pseudostem Cutting
↓
Separation
↓
Washing
↓
Drying
↓
Banana Fibre

- Textiles

✓ Long banana fiber with high tensile strength and stiffness is a promising material for textile.

✓ Japan and Philippines have been employing banana fiber at a large scale for commercial making of garments, table-mats, bags, hangings ropes and curtains.



Lightweight
Comfortable

(a) Fiber

Banana Harvesting → Pseudostem Cutting → Separation → Washing → Drying → Banana Fibre

- Dietary Fiber

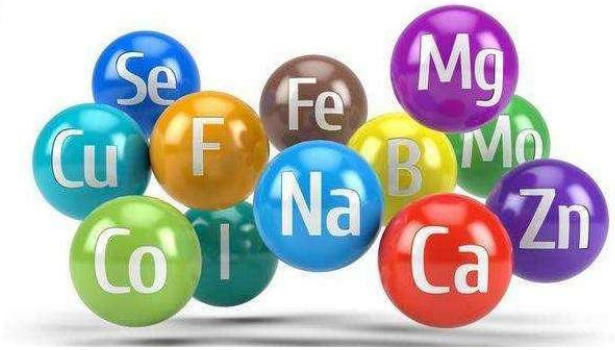
✓ Banana stem is a rich source of fiber helps control obesity and aids in detoxifying the body.
✓ Bread containing 30% banana peel flour is considered as prebiotic, utilized to promote the survival of probiotics.
✓ Instant noodles with added banana flour, rich in dietary fiber, have good nutritional quality and sensory acceptability

Control (B0) B1 B2

The water holding capacity and oil holding capacity of bread with BP flour were higher as compared to the bread control.

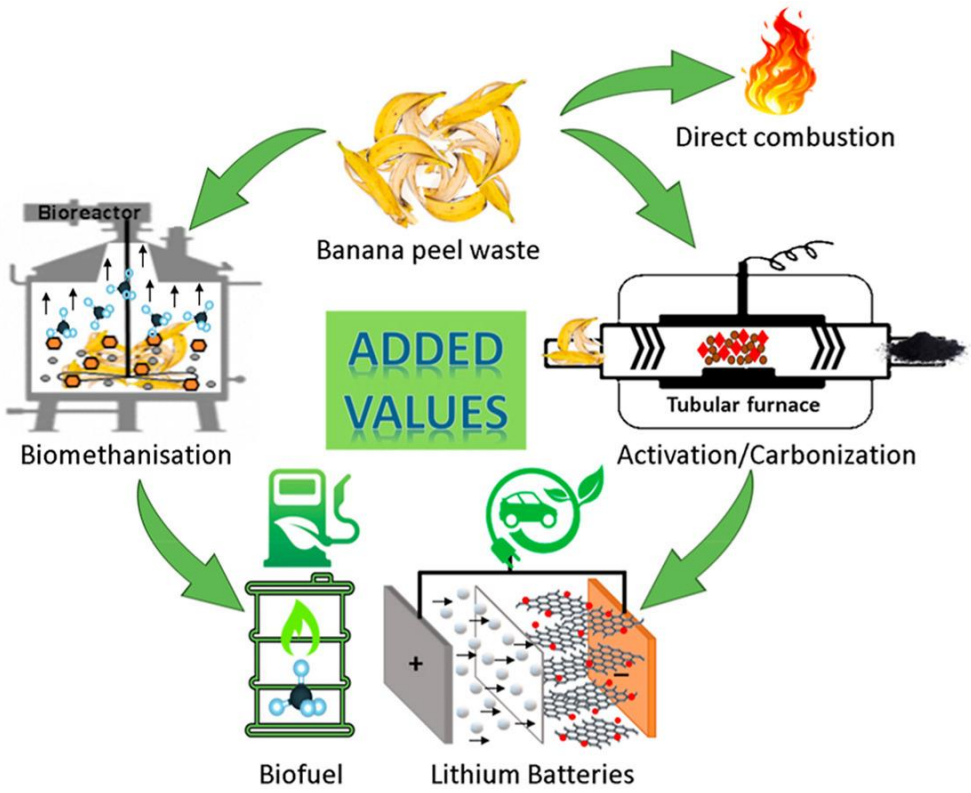
(b) Nutrient Source

- Polyunsaturated fatty acids: linoleic acid and α-linolenic acid
- Essential amino acids: Except for lysine, all essential amino acids are higher than FAO standard.
- Micronutrients: K, P, Ca, Mg
- Oil: amyl acetate



A good feed material for cattle and poultry

(c) Renewable Energy



- Direct combustion: Banana peel waste is a renewable source for generating energy with minimized waste volume and higher calorific (22 MJ/kg).
- Biomethanisation: The anaerobic fermentation of banana peel waste generates renewable biogas and fertilizer.
- Activated carbon: Porous structures with large surface areas to remove heavy metals, pesticides and dyes in wastewater.
- Energy Storage Systems: Use of biomass-derived carbons in banana peels for lithium-ion batteries

Conclusions and Prospects

- ✓Bananas are among the world's leading fruit crops with good nutrition profile.
- ✓Banana normally has a short shelf life and start deteriorating just after plucking.
- ✓Preservation and processing technologies should be further improved to produce banana fruits and products with good quality.

Thank You!

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