Moringa Seed Oil Extraction and Applications

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OUTLINE OF PRESENTATION

1. Introduction
2. Extraction Technology Challenges of Cold pressing
3. Supercritical Carbon Dioxide Extraction
   - Labouratory scale
   - Pilot scale
   - Industrial scale
4. The Effect of Extraction Method on Physicochemical Properties of Moringa Seed Oil
5. Applications
   - high oliec acid content (Omega oil) from seed for health
   - Animal feed from seed cake
   - Environmental and social impacts of an moringa industry
6. Conclusion


Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana
Dr. Nikolaus Foidl, Austria.
The father of moringa
Dr. Vanisha of India
Dr. David Makin
Dr. Newton Amaglo
Certificate of Appreciation
Dr. David Makin
Certificate of Appreciation
Dr. Nikolaus Foidl


Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana


Newton
on his farm

Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana

1.0 INTRODUCTION

Interest in dietary oils and fats and their compositions increasing in recent years.

Oils and fats are a rich source of dietary energy and contain fatty acid components which are essential nutrients (FAO, 1978) .

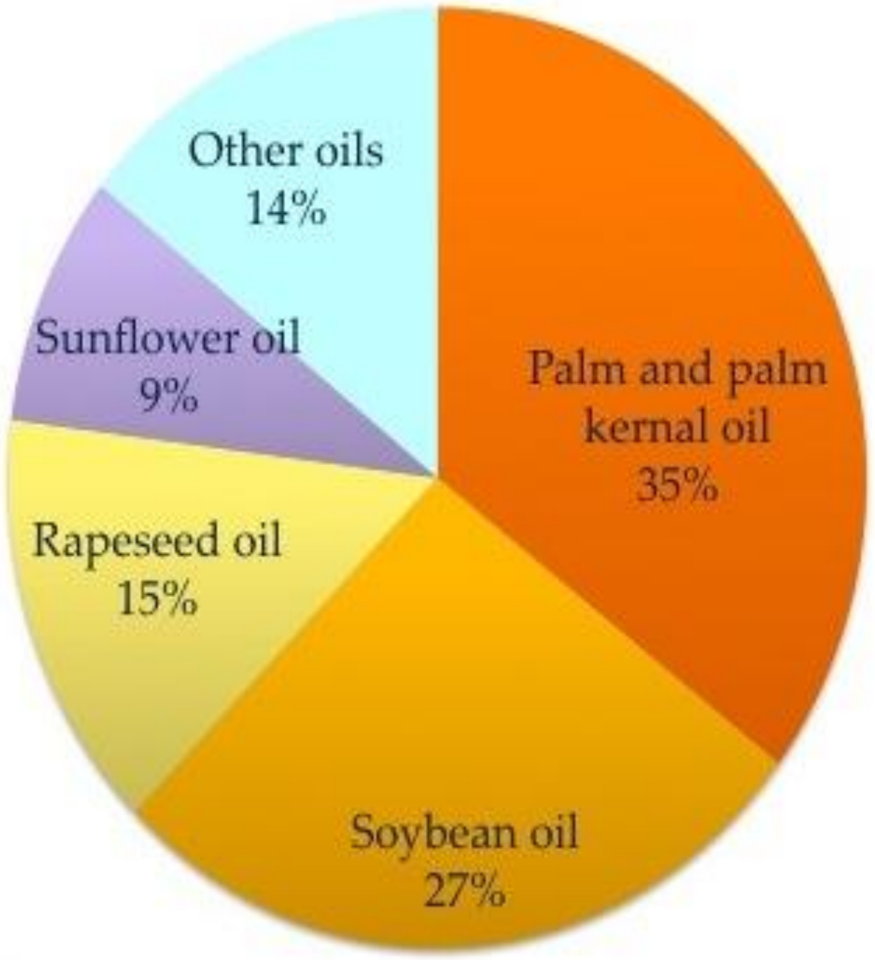
They contribute to the flavor and palatability of many foods.

Thus an increased demand for functional ingredients especially those obtained by “natural” processes (Bernado-Gi, *et al.*, 2002).

Hence the need to look into moringa plant as an a vegetable oil source.

Global Vegetable Oil Production (2011)

100% = 154 million tonnes



Source: Food and Agriculture Organization of the United Nations; data arranged by TigerMine Research

About 80% of the global oil and fat production were vegetable oils and only 20%, with declining tendency, were of animal origin.

About one quarter of global production come from soybean, followed by palm oil, rapeseed, and sunflower.

Coconut and palm kernel oil (laurics) contain a high percentage of saturated C12 and C14 fatty acids and are most important for the production of surfactants.

Saturated fats and oils have been associated with heart diseases (FAO, 1978) and so there is an increasing demand for unsaturated fats and oils in the world market.

Vegetable oils rich in oleic acid like

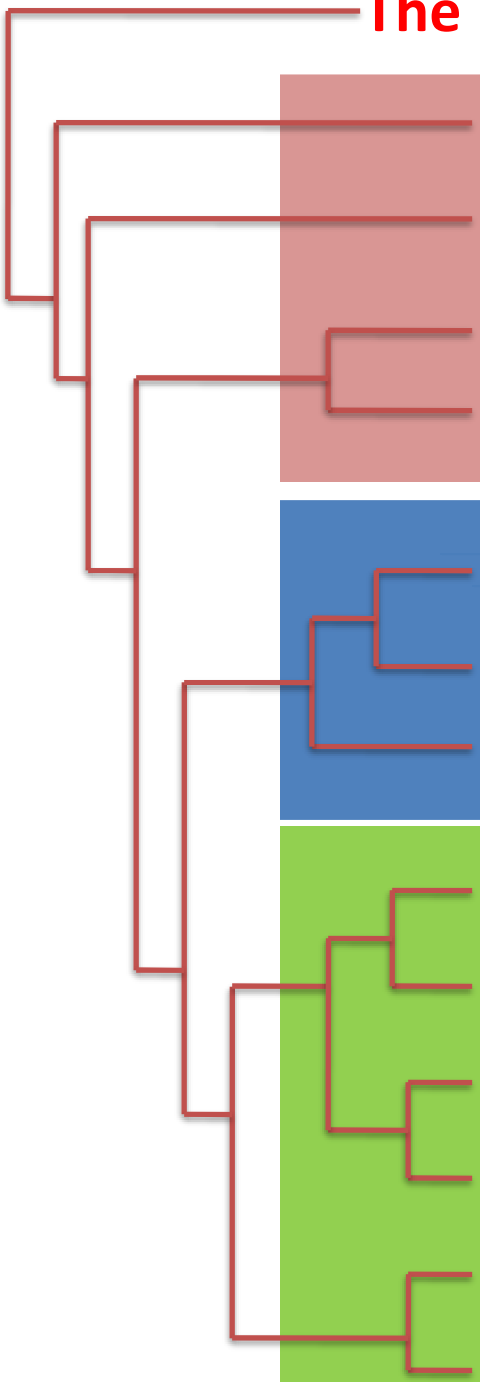
- olive (80%),
- tea seed (85%),
- pecan (85%) and
- peanut (60%) oils

are higher priced in relation to soybean oil and sunflower oil.

THE MORINGA PLANT AND SEED OIL

- Family - Moringaceae
- Genus - Moringa
- Common names - horseradish tree, drumstick tree, West India Ben tree, Never Die tree, Radish tree (Ramachandran *et al*., 1980).
- Number of species - 13
- Most important - *Moringa oleifera*, *M. stenopetala*
- Origin - Sub-Himalayan tracts of the Indian subcontinent
- Occurrence, cultivation - all over the tropics
- Growth and Size - fast growing perennial tree, grows to 7-12m height and a diameter of 20-40 cm at chest height.

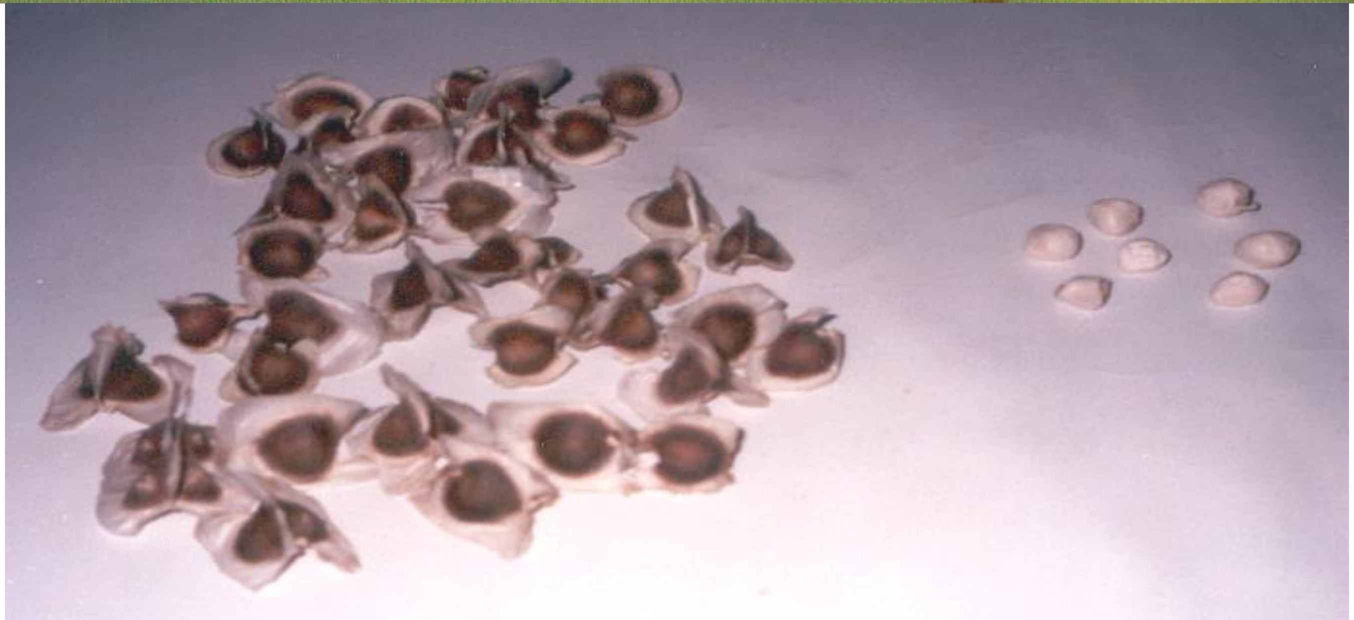
The 13 members of the Moringaceae family



Species	Origin	
M. drouhardii	Madagasca	Bottle Trees
M. hildebrandtii	Madagasca	
M. stenopetala	Kenya, Ethiopia	
M. ovalifolia	Namibia, Angola	
M. concanensis	India, Pakistan, Bangladish	Slender Trees
M. oleifera	India	
M. perigrina	Arabia, Red Sea area	
M. arborea	Kenya	Tuberous shrubs and trees of northern Africa
M. rivae	Kenya, Ethiopia	
M. borziana	Kenya, Somalia	
M. pygimaea	Somalia	
M. longituba	Kenya, Ethiopia, Somalia	
M. ruspoliana	Kenya, Ethiopia, Somalia	


Moringa Drouhardii
Moringa Hildebrandtii
Moringa Oleifera PKM1
Moringa Ovalifolia
Moringa Oleifera
Moringa Stenopetala
Healing Moringa Tree
www.HealingMoringaTree.com

Moringa oelifera WHOLE SEED



AVERAGE SIZE OF *Moringa oleifersa* SEED

Moringa stenopetala

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Kumasi, Ghana





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Kumasi, Ghana

Moringa peregrina

Moringa peregrina

Dr Engineer Saudi Ibrahim AlBawi[1]

[1]Tabuk University, Saudi Arabia

Farm Location: Al-Ula city, Al-Ula suburb

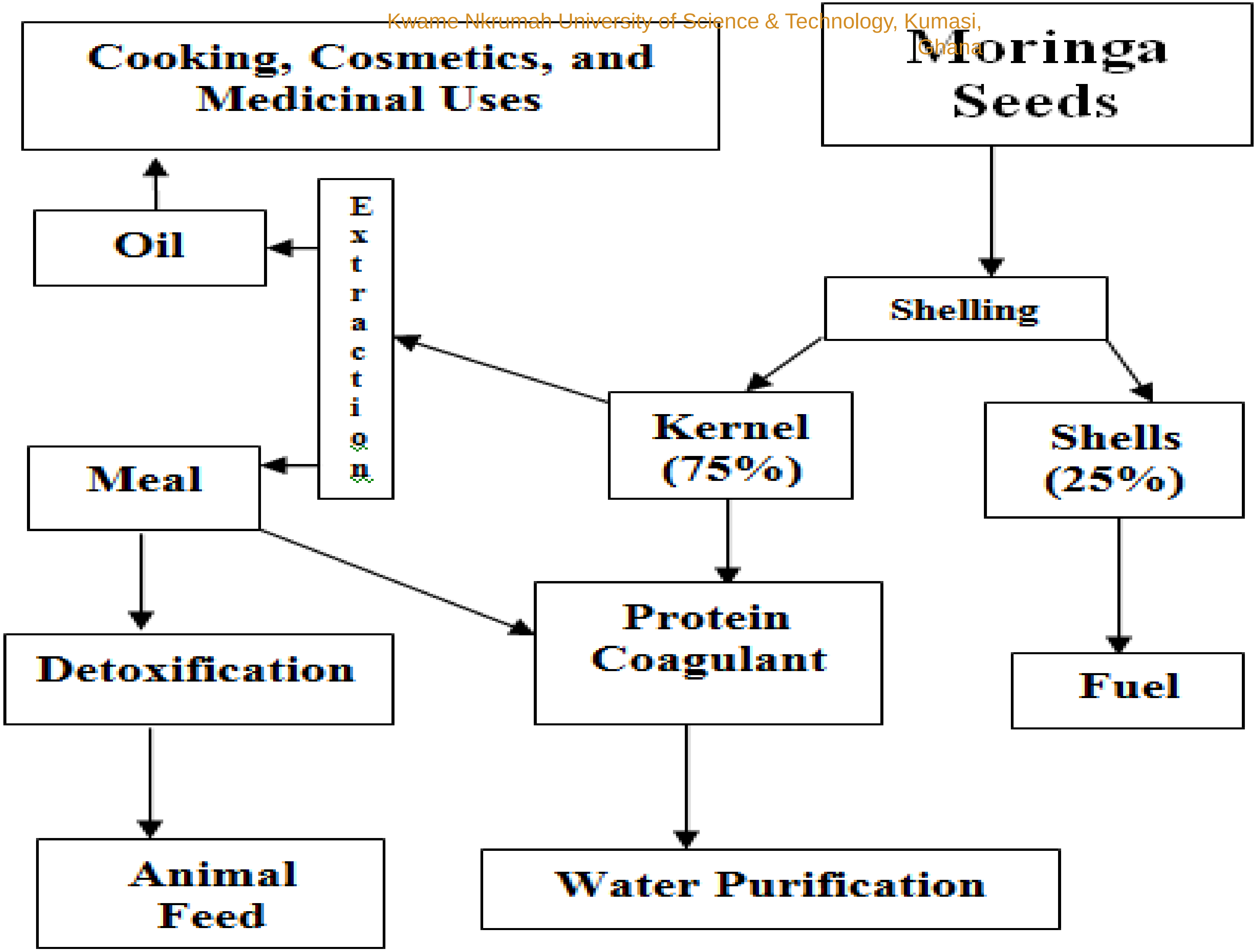
2. EXTRACTION TECHNOLOGY CHALLENGES

2.1 Moringa seed oil is **traditionally** produced by

- **boiling the seeds with water** (Somali, *et al*., 1984) but
  - It has a high level of physical exertion,
  - is time and labor intensive.

2.2 Mechanical cold-pressing involves

- crushing the seed in a heat-controlled process
- Preservation of oil color, flavor, nutritional quality, structure of crucial fatty acids and proteins.
- Nickel or Chromium in steal alloys acts as Catalyse of moringa oil and protein
- Cold-pressing has a low efficiency and a
- Has a high chances of thermal degradation of the oil.


Cooking, Cosmetics, and Medicinal Uses
Moringa Seeds
Oil
Extraction
Shelling
Kernel (75%)
Shells (25%)
Meal
Protein Coagulant
Detoxification
Fuel
Animal Feed
Water Purification

Green world campaign

American funded project in Kenya, Africa

Contact: Marc Barasch, CEO

E: marc@greenworld.org

www.greenworld.org

www.piteba.com/eng/prices_eng.html

Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana

Massachusetts Institute of Technology (MIT) Kwami Williams (moringaconnect@mit.edu) Ghana

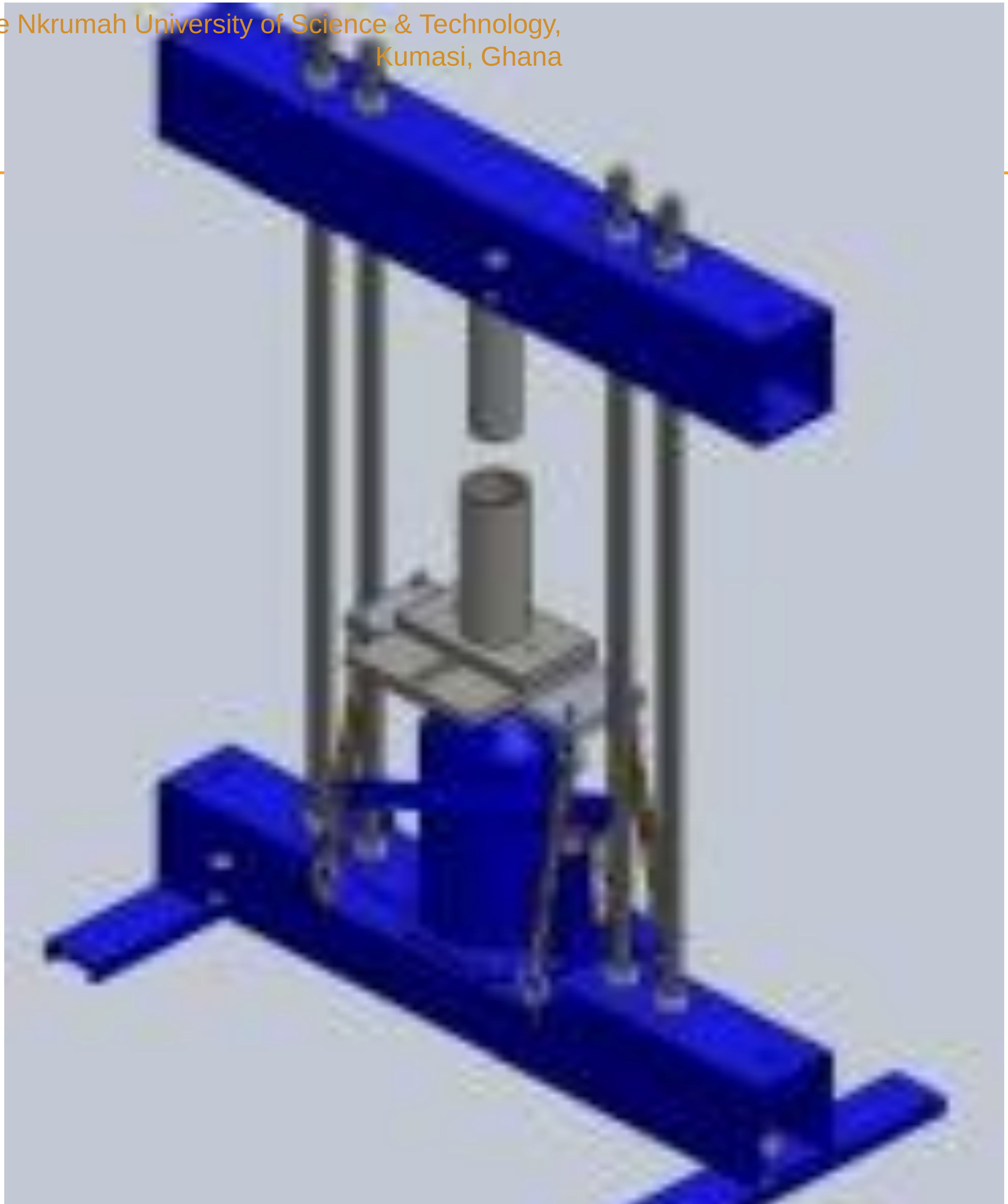


Table top Screw press

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ANDAVAR LATHE WORKS

86,New Bus Stand Rode,
Near Moolapattarai,
Erode - 638 003.
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+91 98427 12045
+91 98427 22045
www.andavarlatheworks.com
Email:andavargroup@gmail.com


honglemachinery.ecvv.com

Cold Press Machine

2.3 Solvent Extraction of Vegetable Oils

Solvent extraction of seed oils is commonly used and can be a

- vapour,
- supercritical fluid, or
- liquid,

and the sample can be a gas, liquid or solid (Bekman, 2009).

The oil yield obtained is usually higher than that of mechanical method.

Organic solvents such as alcohols, acetone, hexane and benzene (hydrocarbons) are used .

These organic solvents, are not environmentally friendly and their incomplete removal from the oil after extraction leaves unpleasant residual effects behind.

There are new and strict regulations about the use of organic solvents in the food industry have brought about the need to research into alternate 'green' oil extraction technologies.

The use of enzymes as green catalysts, have also been used to improve the efficiency of oil extraction (Rosenthal, *et al.*, 1996) but expensive

In order to fill in the technology gap created by this situation, several authors have proposed Supercritical CO_2 extraction of oil from seeds (Salgin, 2007)

2.4 SUPERCRITICAL CO2 EXTRACTION

- Supercritical carbon dioxide is an effective extraction technique without the pitfalls of traditional methods,
- CO_2 is
  - environment friendly,
  - safe,
  - cheap,
  - non-toxic,
  - non-carcinogenic,
  - non-flammable, and
  - having modest critical conditions.
- It can be applied to a wide range of chemical and biochemical extraction processes.
- varying temperature and pressure can lead to obtaining desirable compounds (Babovic, *et al.*, 2010).

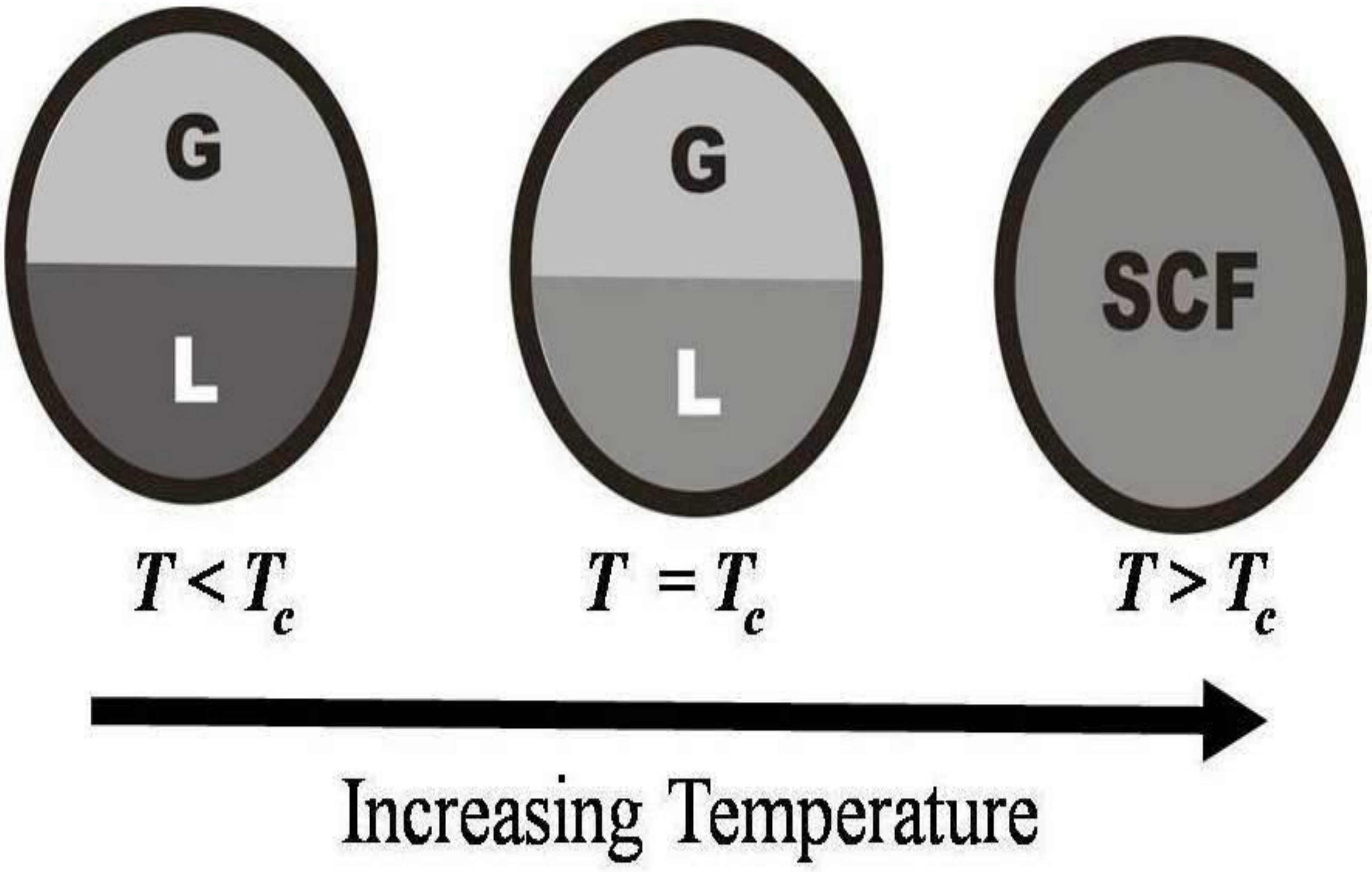
- **Extraction of seed oils by Supercritical carbon dioxide is an effective extraction technique**
- **without the pitfalls of traditional methods, such as thermal degradation,**
  - **low yield, or**
  - **solvent contamination.**
- **The technology has been used in processes, such as in**
  - **food,**
  - **pharmaceutical,**
  - **biochemical industries,**
  - **polymer processing and**
  - **environmentally friendly chemical processing**

(Mustafa and Turner, 2011; Zaidul, *et. al.*, 2007).

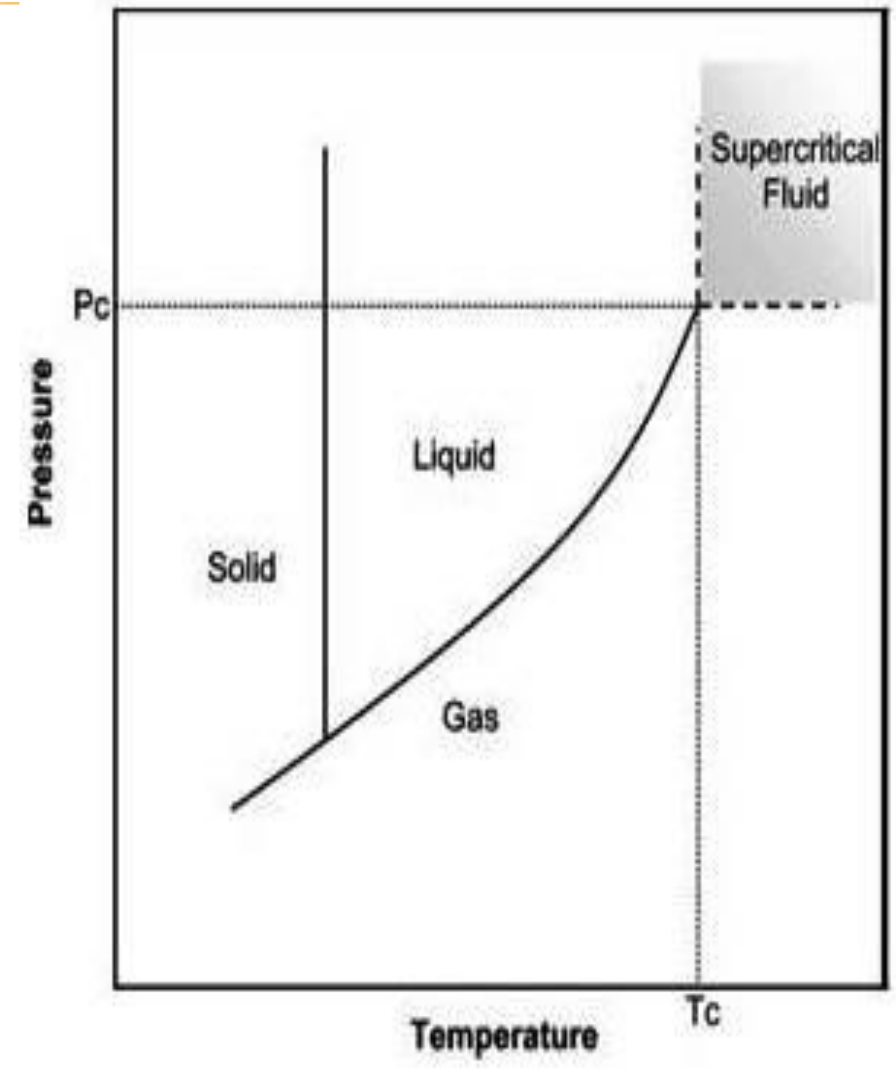
The only drawback of SFE process is the high investment cost as compared to traditional methods (Herrero, *et. al.*, 2006).

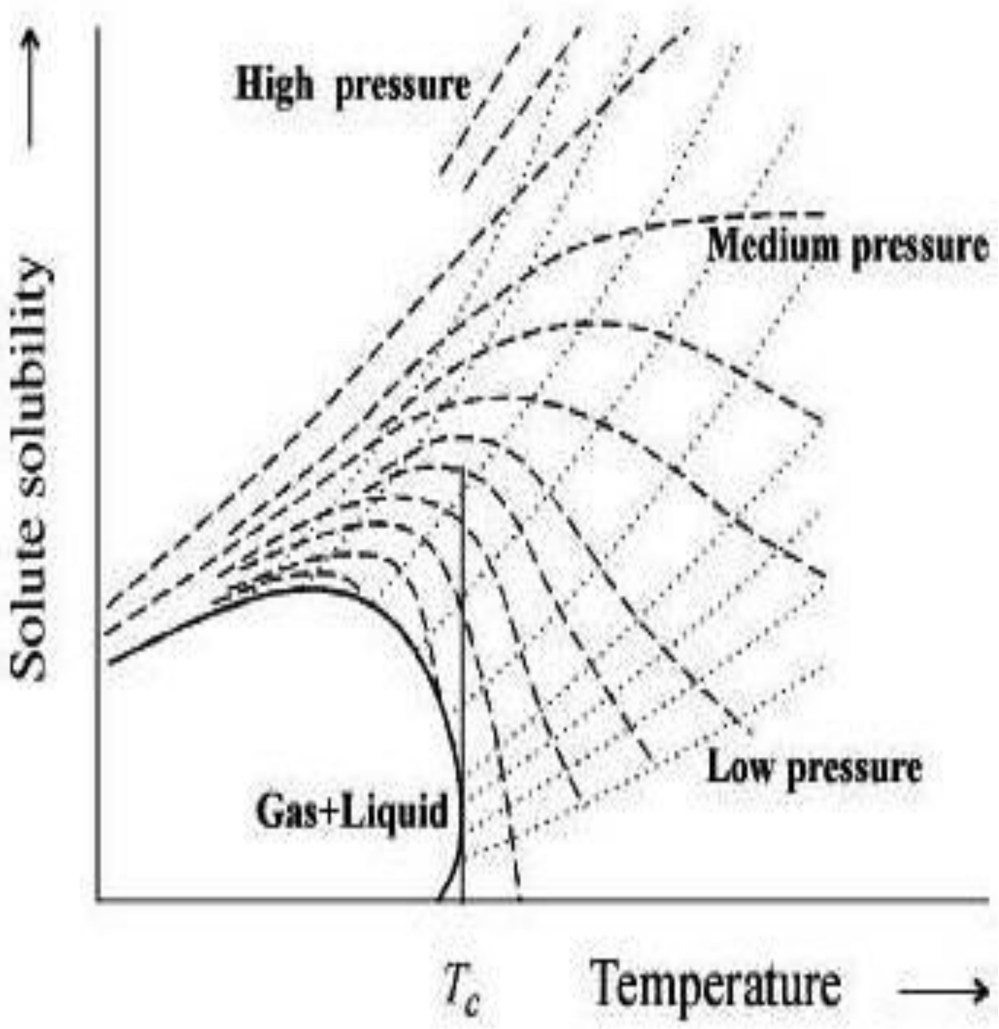
WHAT IS A SUPERCRITICAL FLUID?

THE PHYSICAL PROPERTIES OF SCF IN LIQUID AND A GAS PHASES



PHASE DIAGRAM AND SOLUBILITY BEHAVIOUR OF CO_2





SEED PRE-PROCESSING

This is a parameter that can largely influence the separation performance.

For example,

1. **solid drying, ≤ 5 % moisture preferred**
2. **flaking or milling to ≤ 0.1 -0.2mm and**
3. **particle size optimization**
4. **optimization of Extraction parameters**

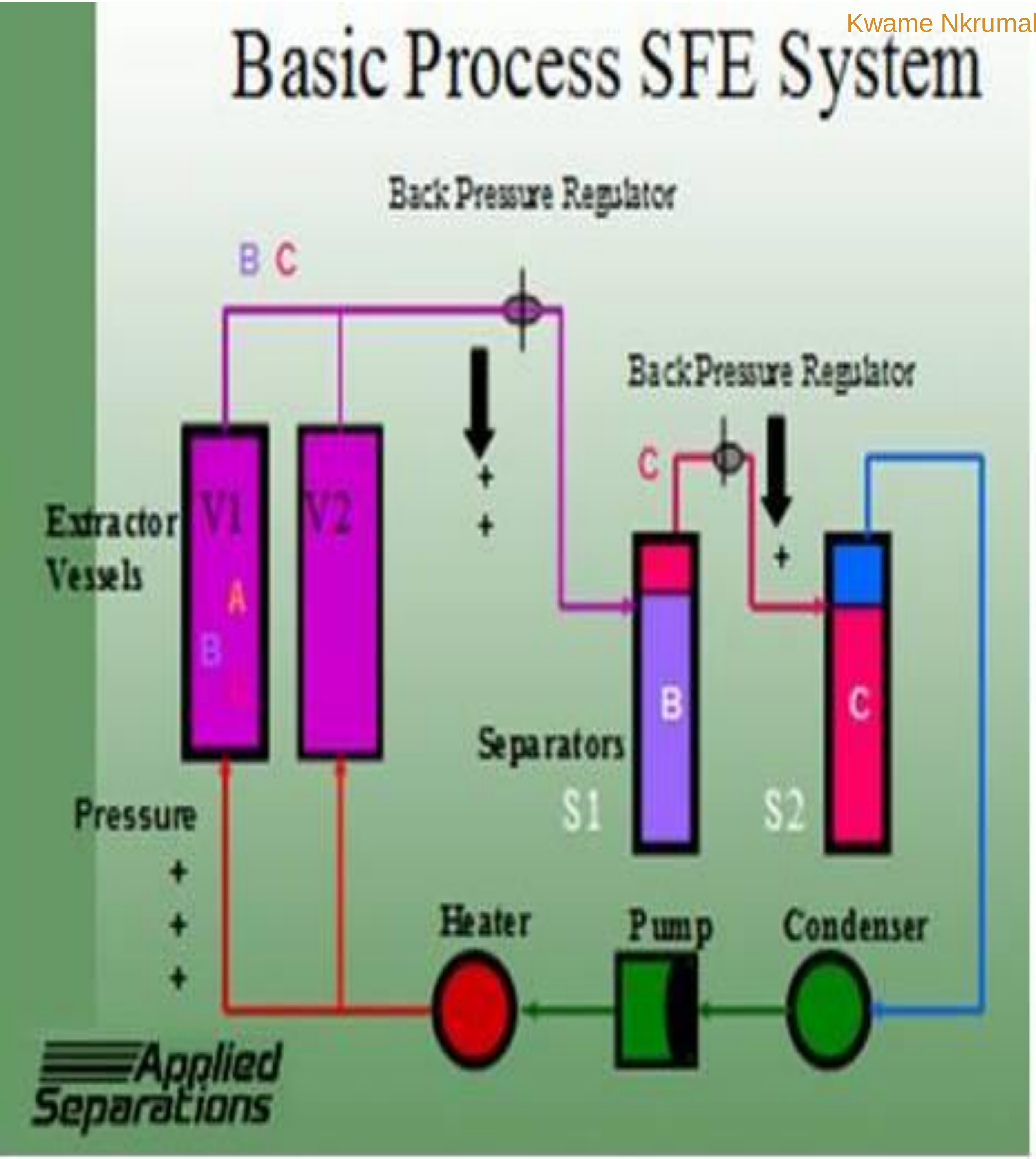
have, as a rule, be taken into account.

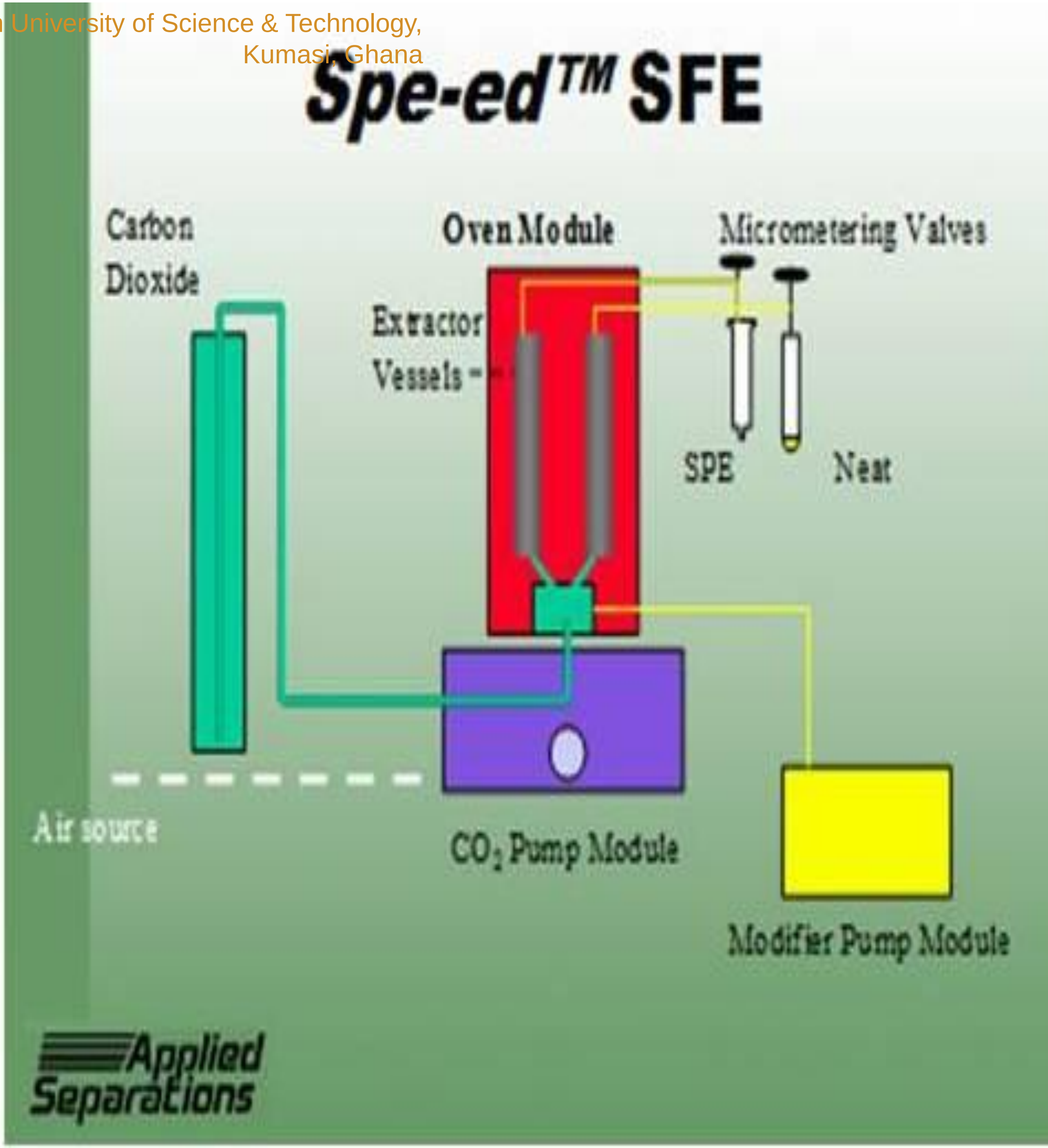
PHYSICAL APPEARANCE OF *MORINGA OLEIFERA* SEED AND SEED FRACTIONS

Milling is to reduce the surface area of the particle and thereby exposing the oil more for effective extraction


Supercritical CO2 defatted
seed meal

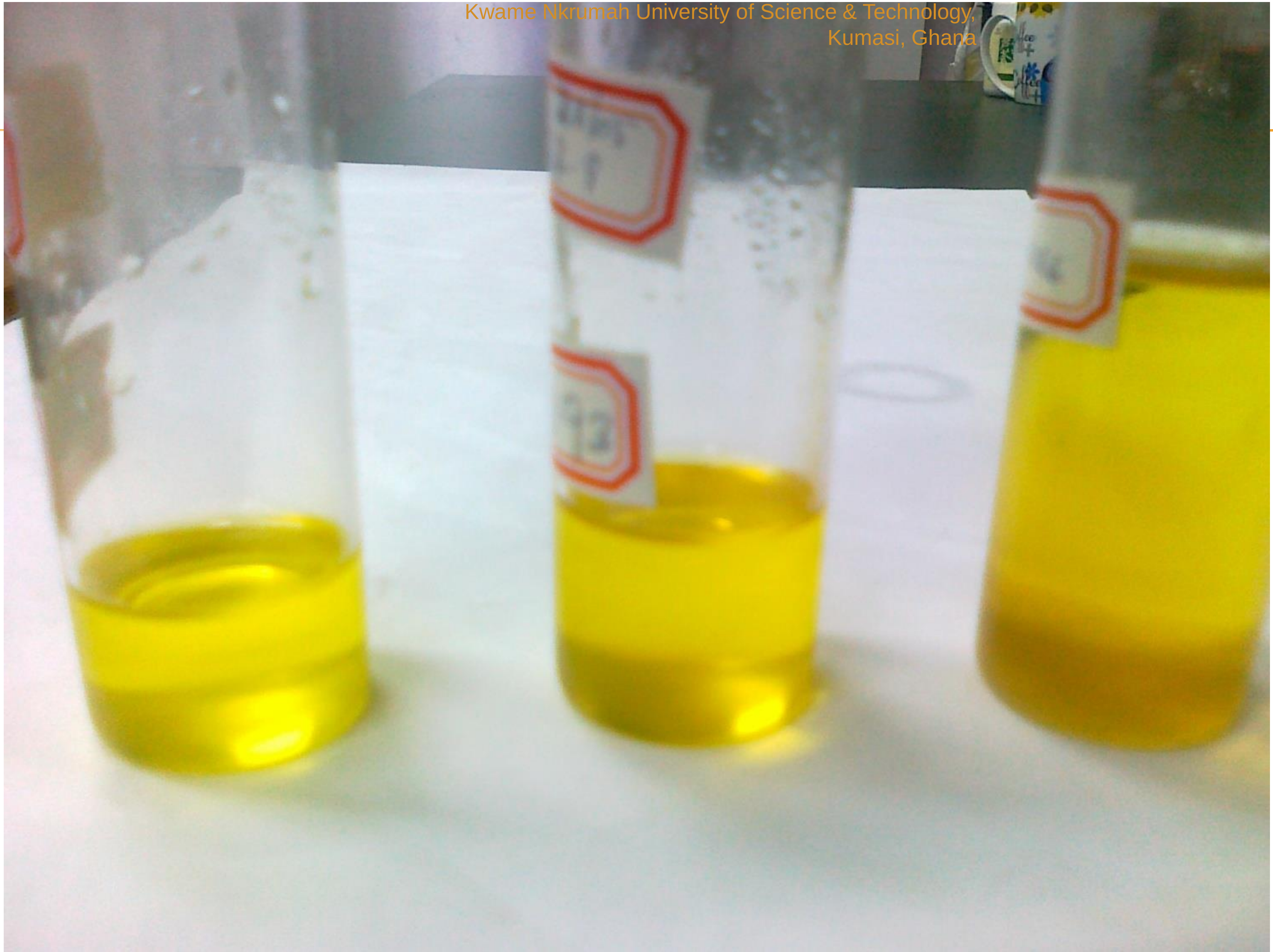

Cold pressed defatted
seed meal


Basic Process SFE System
Back Pressure Regulator
B C
Back Pressure Regulator
C
Extractor Vessels
V1
V2
A
B
Separators
B
C
S1
S2
Pressure
Heater
Pump
Condenser
Applied Separations


Spe-ed™ SFE
Carbon Dioxide
Oven Module
Micrometering Valves
Extractor Vessels
SPE
Neat
Air source
CO_2 Pump Module
Modifier Pump Module
Applied Separations

USING SUPERCRITICAL CO2 TO EXTRACT OIL

Kwame Nkrumah University of Science & Technology, Kumasi, Ghana



2.4 Pilot Scale Supercritical Extractions operations

Pilot Scale Supercritical CO2 set up

Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana

SUPERCRITICAL CO_2 EXTRACTIO

SUPER AND SUBCRITICAL EXTRACTION UNIT

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SUPERCRITICAL CO2 OIL

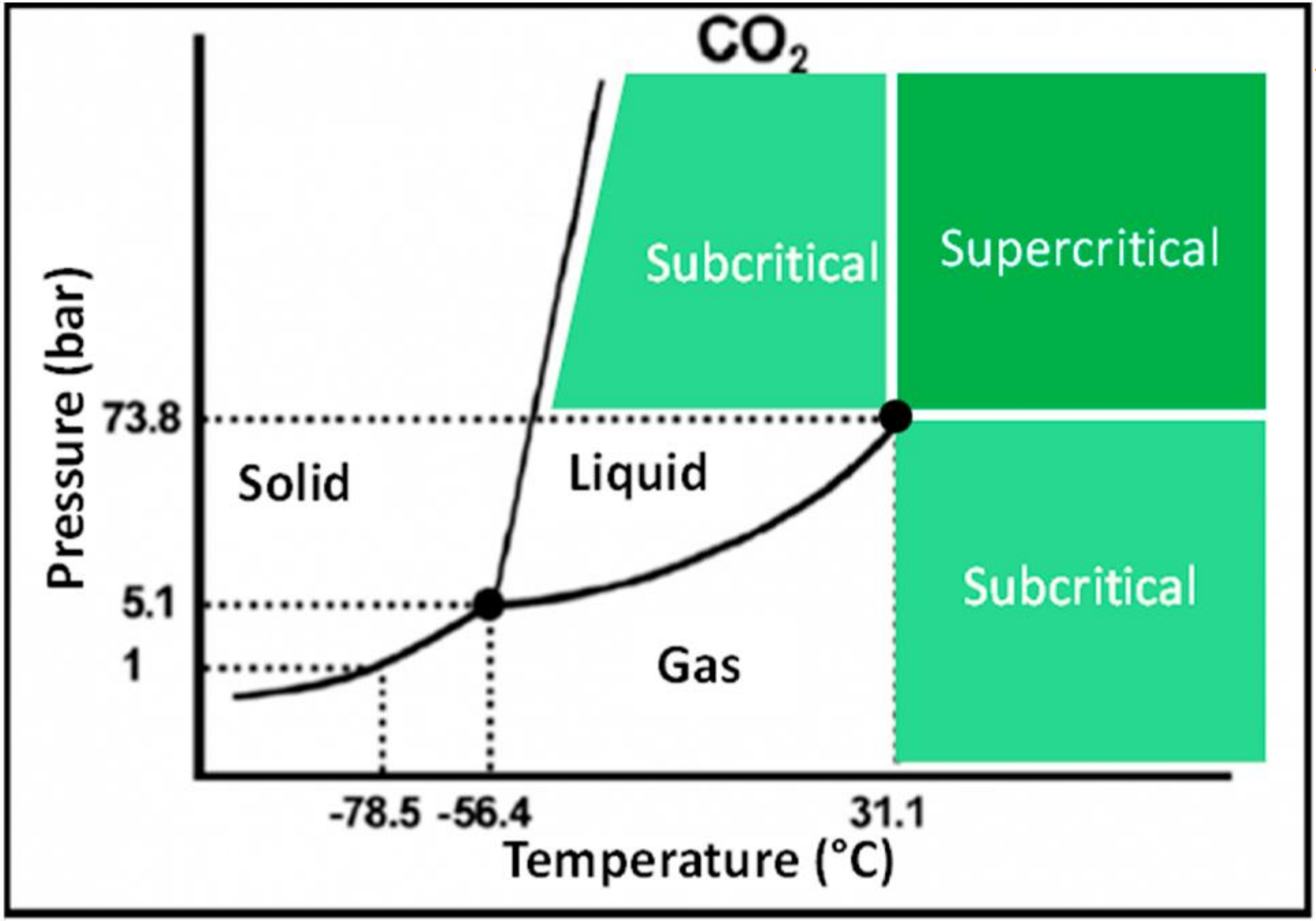
COLD PRESS OIL AND SEED CAKE

Fig. 4.4 Cold pressed oil (12.0 % w/w) and Supercritical CO_2 extracted oil (31.8% w/w)

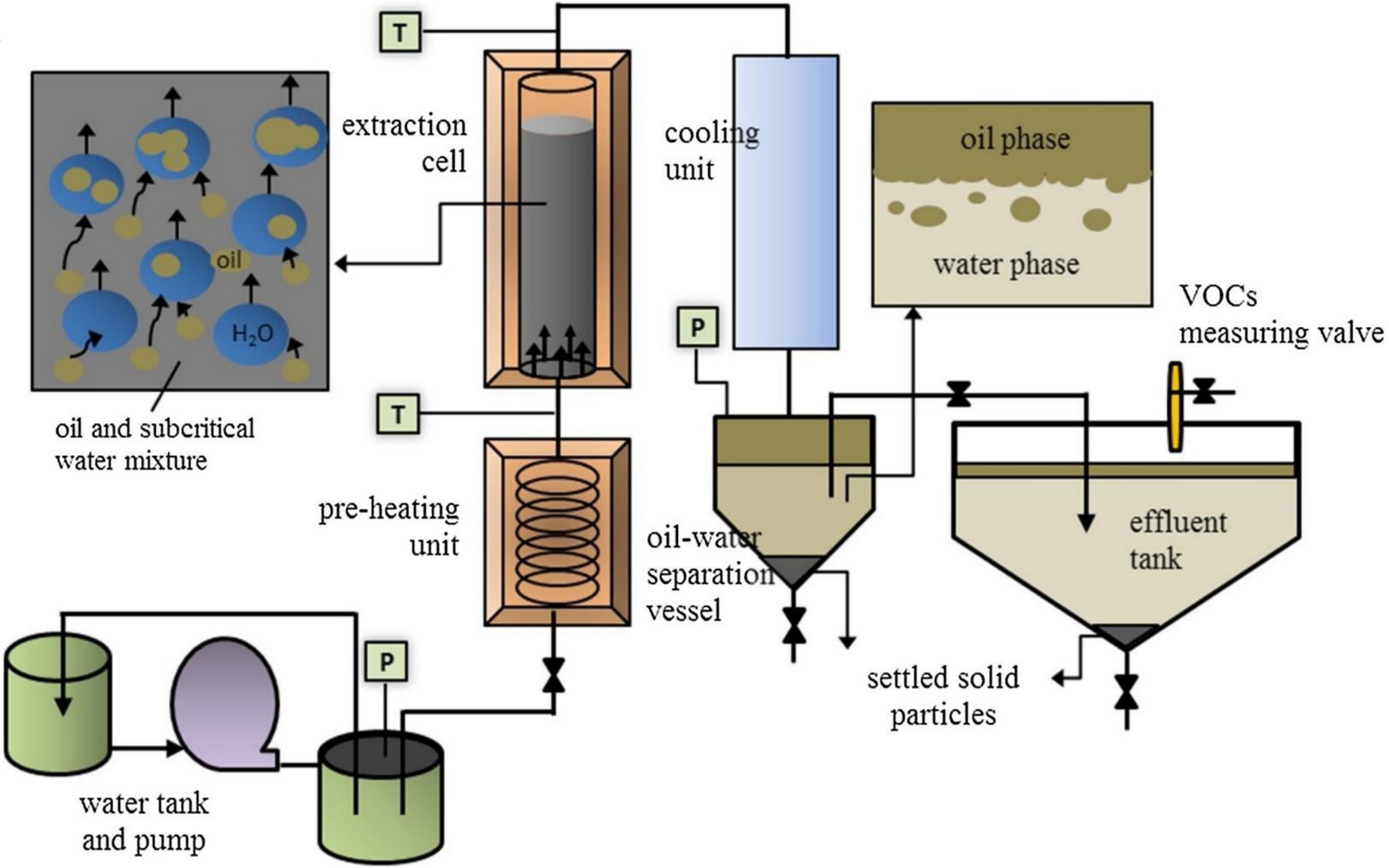
COLD PRESS & SUPERCRITICAL CO_2


Cold Pressed oil
in China
Supercritical CO_2 oil

CO2 PHASE DIAGRAM



SCHEMATIC OUTLINE



Christy Hou
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Pilot Scale Subcritical Ectraction Unit (5L\100L)

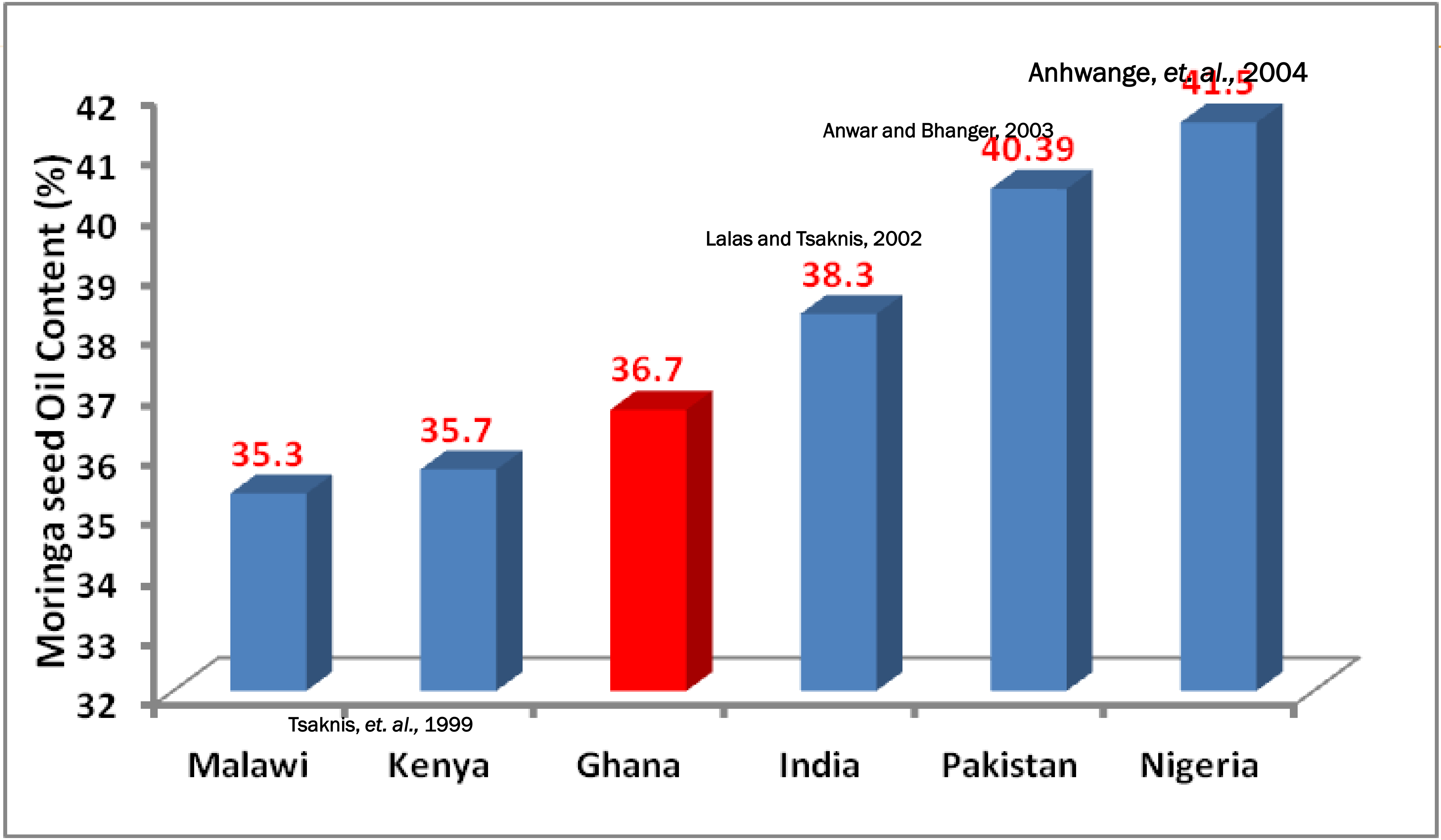
Kwame Nkrumah University of Science & Technology, Kumasi, Ghana

INDUSTRIAL SCALE 50-80 DAILY EXTRACTION CAPACITY

COMPARISON OF DIFFERENT METHODS OF EXTRACTION OF WHEAT GERM OIL

Technical and economic indicators / Comparison Project	Technology Type			
	Subcritical solvent extraction technology	Screw Press law	6 Solvent Extraction	Supercritical CO2 Extraction
Wheat germ oil quality	Excellent	Not good	General	Excellent
Investment in equipment	Moderate	Low	Moderate	Great
Oil yield (crude oil)	About 8.5%	About 5%	About 8.5%	About 8.0%
Residual meal	≤1%	≥4.5%	≤1%	≤1.5%
Wheat germ meal quality	Excellent	Poor	Difference	Excellent
Dunliaohaorong	≤6kg	No	≤13kg	Very high
Heat-sensitive material impact on the	No	Great	General	No
Energy Consumption	Low	Moderate	High	High
Degree of automation	High	Low	High	High
Impact on the environment	Pollution	Pollution	Pollution	Pollution

Comparing Oil Content by different authors



Comparing Major Oil seed

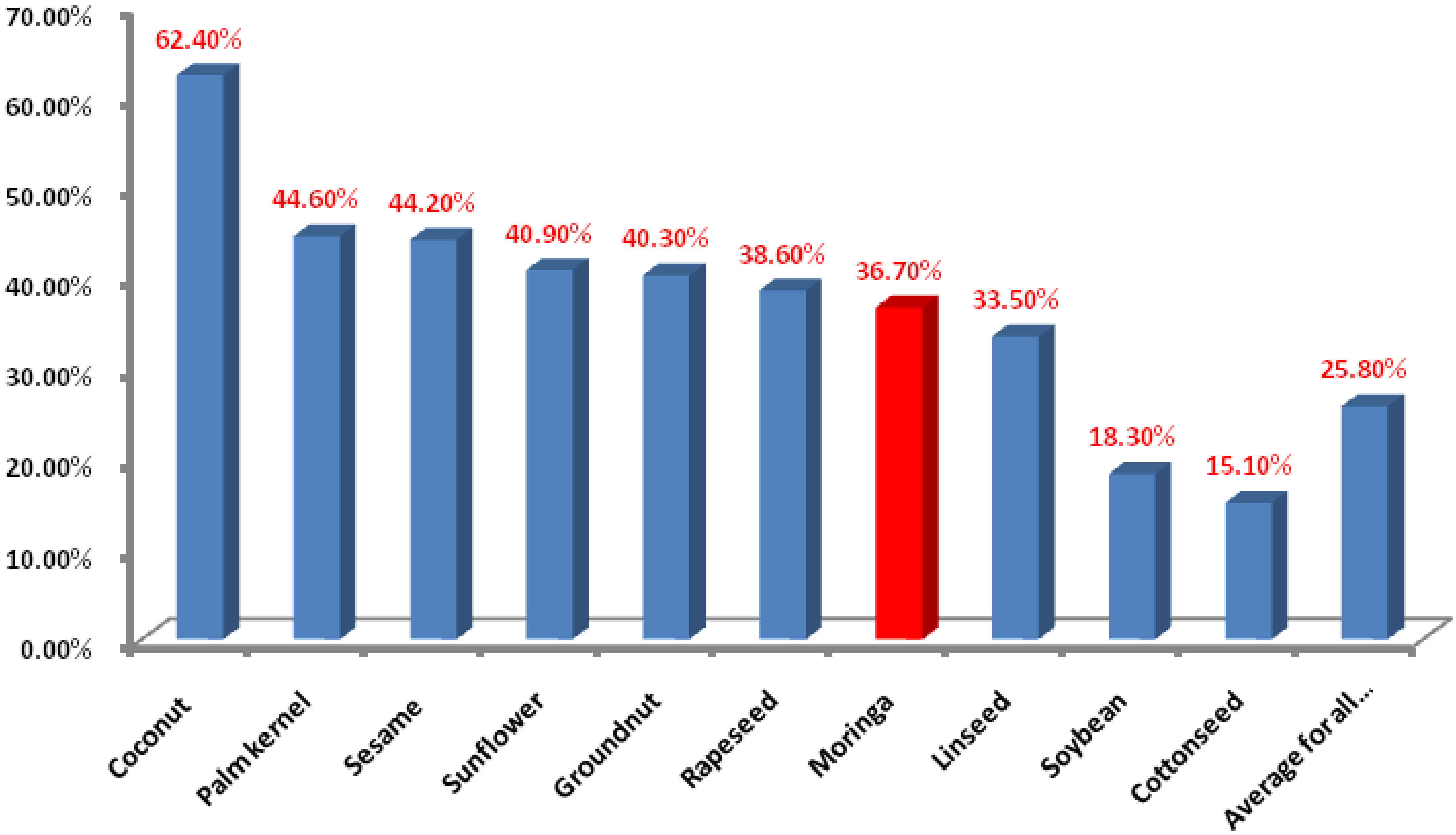


Fig. 4.5 The *Moring oleifera* seed oil samples at room temperature

Table 4.4 Physico-chemical properties of *Moringa oleifera* seed oil

Chemical index	Oil sample					
	L1	L2	L3	L4	L5	Virgin olive oil[a]
Saponification Value (mg KOH/g)	143.33	155.66	147.31	167.52	158.23	188
Peroxide value (Meq/Kg)	0.07	0.360	--	0.028	0.043	0.76
Acid Value (as oleic acid in mg/g)	1.33	2.38	4.16	1.02	5.26	0.98
Iodine value (g of I/ of oil)	62.12	63.37	64.175	67.31	64.48	80.01
	0.898	0.896	0.910	0.904	0.898	0.915

[a] Data from Lalas and Tsaknis, 2002

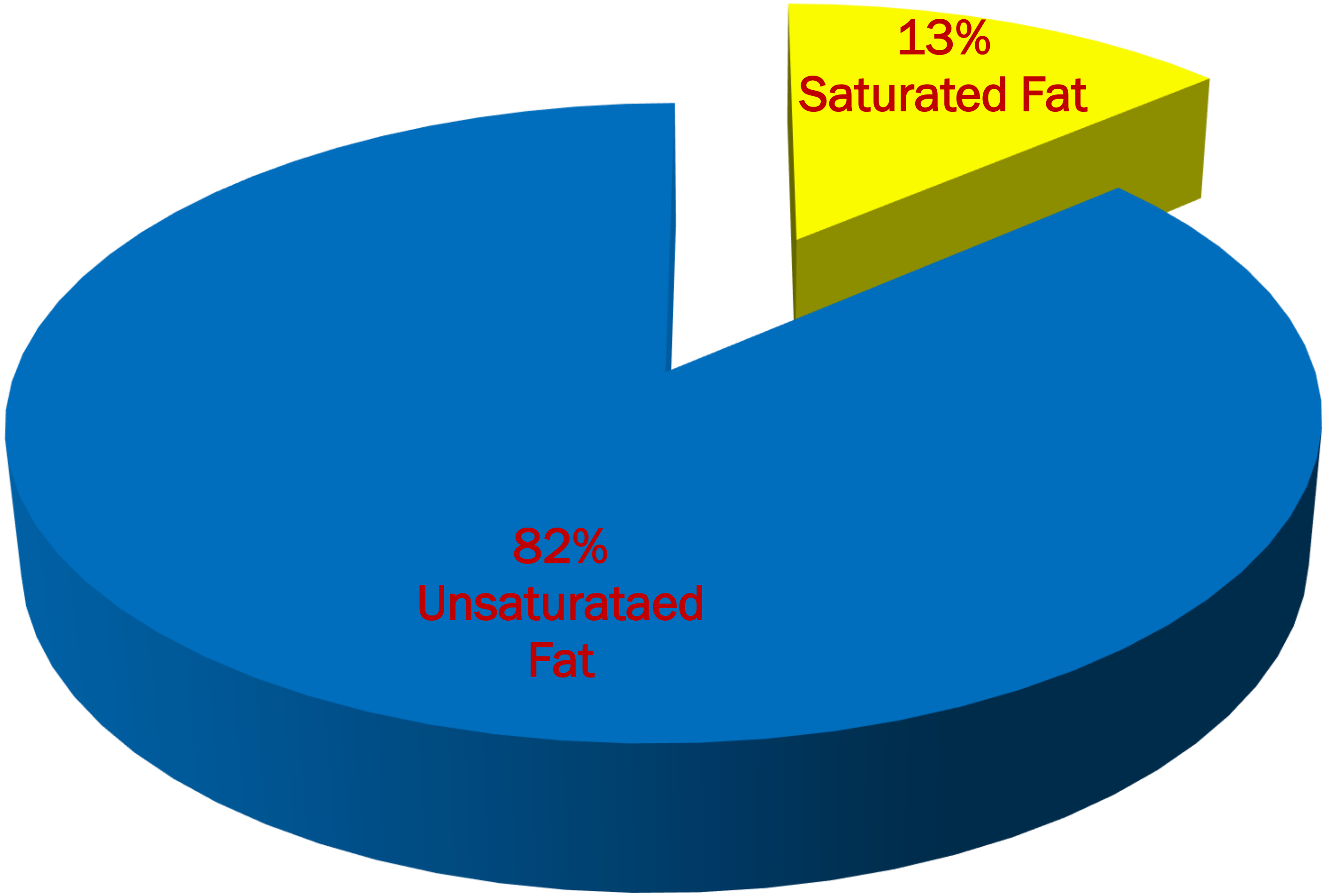
TABLE 1: SENSORY EVALUATION OF *MORINGA OLEIFERA* SEED OIL SAMPLES

Sensory index	Colour	Odour	Taste
Cold Press（Ghana L1）	Yellow	Pungent	Partially Taste
Cold Press（USA L2）	Yellowish Brown	Pungent	Partially Taste
Cold Press（Kenya L3）	Brown	Faint	Partially bitter
SCF CO_2（L4）	Bright Yellow	Faint	Normal Taste
Cold Press（China L5）	Yellowish Brown	Faint	Normal Taste

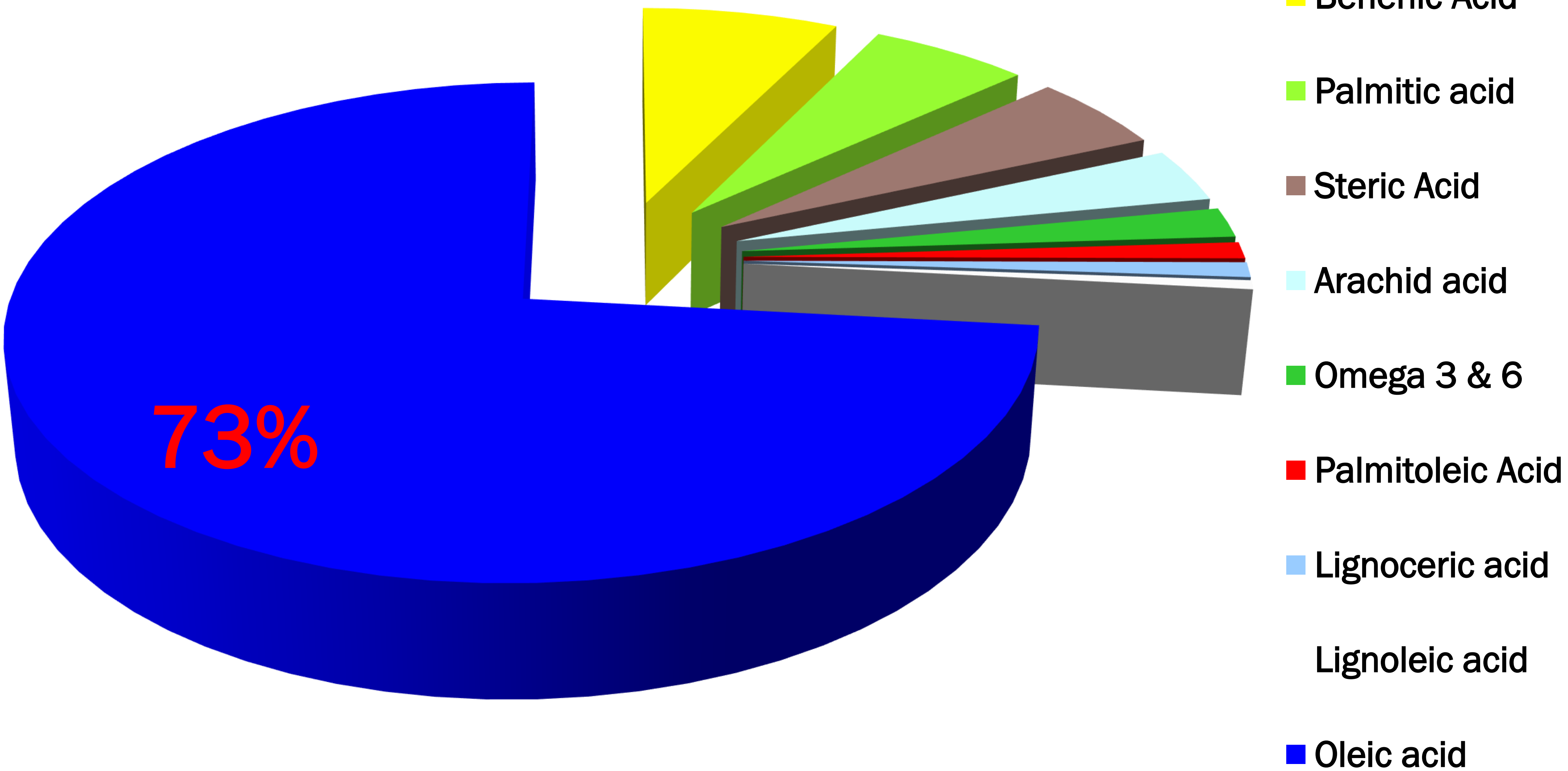
MORINGA OIL (BEN OIL)

- the oil has a high retention potential for fragrances so you try to get the oil itself as a raw material
- the oil used for extracting fragrances from different flowers etc.
- The high oliec acid allows for longer storage and high-temperature frying
- It is more stable than Canola oil, soybean oil and palm oil
- Blending ben oil with soybean and sunflower oil enhances the oxidative stability of the mixture

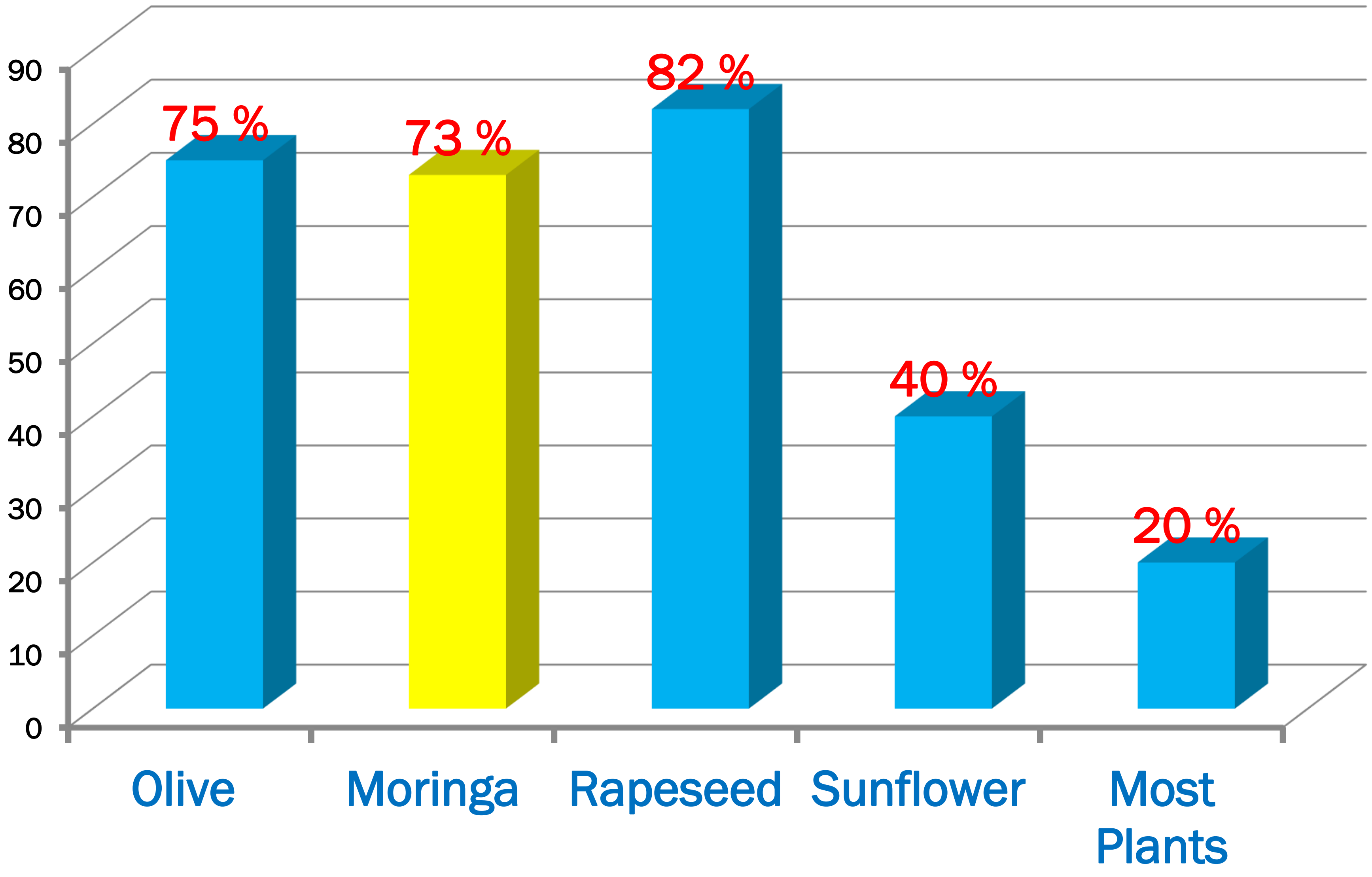
MORINGS SEED OIL CONTENT & COMPOSITION



UNSATURATED FATTY ACID PROFILE



OLEIC ACID CONTENT COMPARED



OLEIC ACID IN OLIVE OIL

+18-carbon long monounsaturated fatty Acid (MUFA)

+reduces incidence of cardiovascular disease

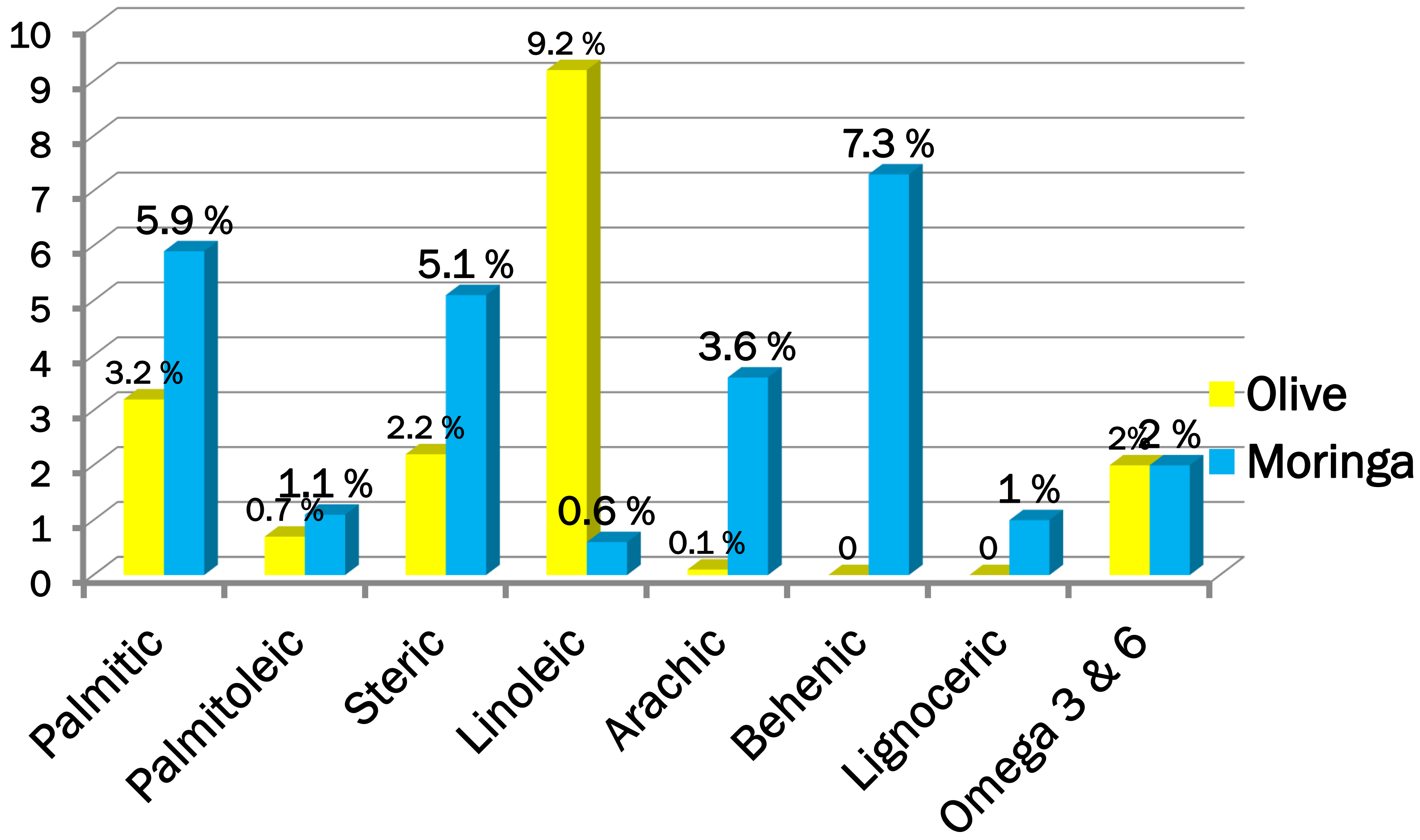
+ reduces incidence risk factors like heart disease, stroke and high blood pressure

+reduces atherosclerosis (hardening of the arteries)

+significantly lover breast cancer incidence among women

+regulates the blood glucose levels

OTHER MONOUNSATURATED FATTY ACIDS IDENTIFIED INCLUDE



OMEGA-3 AND OMEGA-6

- Similar to olive and rapeseed oils, Moringa oil also contains 1-2% Essential Fatty Acids being omega-3 and omega-6
- Initially found in animal fat alone eg. fish liver oils
- EFA favorably affect atherosclerosis, coronary heart disease, inflammatory disease, depression and even behavioral disorders(temper tantrums, learning and hyperactivity)

STEROL COMPOSITION OF DEGUMMED MORINGA OIL CONT…..

Determination	Cold Press	*n*-Hexane	Chloroform: Methanol	*P*	Virgin olive oil	*P*
Campestanol	0.36 (0.05)	0.33 (0.05)	0.33 (0.03)	NS	0.29 (0.03)	NS
Stigmasterol	23.1 (1.63)	23.06 (1.13)	22.5 (1.19)	NS	0.6 (0.09)	0.05
Ergostadienol	0.3 (0.04)	0.35 (0.04)	0.36 (0.04)	NS	Not detected	0.05
Clerosterol	2.08 (0.12)	1.22 (0.09)	1,80 (0.09)	NS	0.54 (0.26)	0.05
β-Sitosterol	45.58 (3.66)	43.65 (2.79)	44.05 (3.02)	NS	64.3 (4.35)	0.05

(Tsaknis et al., 1999)

STEROL COMPOSITION OF DEGUMMED MORINGA OIL CONT……

Determination	Cold Press	*n*-Hexane	Chloroform: Methanol	*P*	Virgin olive oil	*P*
Stigmastanol	0.76 (0.10)	0.64 (0.17)	0.74 (0.11)	NS	0.4 (0.08)	0.05
Δ5-Avenasterol	8.46 (0.92)	11.61 (1.14)	10.43 (1.01)	NS	16.77 (1.23)	0.05
Δ7, 14 Stigmastadienol	0.52 (0.22)	0.39 (0.10)	0.4 (0.09)	NS	Not detected	0.05
28, Isoavenasterol	0.27 (0.12)	0.25 (0.11)	0.4 (0.09)	NS	Not detected	0.05
Δ7, 14 Stigmastanol	0.35 (0.14)	0.85 (0.29)	0.51 (0.19)	NS	<0.1	0.05
Δ7, Avenastenol	0.53 (0.07)	Not detected	1.15 (0.19)	NS	0.29 (0.06)	0.05

(Tsaknis et al., 1999)

TOCOPHEROL COMPOSITION OG NON DEGUMMED MORINGA OIL

Determination	Cold Press	*n*-Hexane	Chloroform: Methanol	*P1*	Virgin olive oil	*P2*
α-Tocopherol	5.06	15.38	2.42	0.05	88.5	0.05
	(0.67	(0.68)	(0.37)		(6.30)	
ᵞ-Tocopherol	25.4	4.47	5.52	0.05	9.9	0.05
	(1.16)	(0.87)	(0.69)		(0.65)	
ᵟ-Tocopherol	3.55	15.51	12.67	0.05	1.6	0.05
	(0.45)	(0.99)	(0.55)		(0.86)	

(Tsaknis et al., 1999)

Fatty acids profile of *Moringa oleifera* oil with profile of palm, rapeseed (Canola), soyabean and sunflower oils shown for comparison purposes

Fatty Acid	*MO*	*MO*[e]	*MS*[i]	*MP*[j]	*MC*[d]	Virgin Olive Oil[f]	Palm	Corn[g]	Rape seed[a]	Soya bean[a]	Sun flower[a]
C12:1	0.01	-	-	0.08	-	-	-	-	-	-	-
C14:0	0.11	0.13	0.10	8.67	-	<0.01	1.1	0.13	-	-	-
C16:0	8.93	6.5	6.01	1.64	11.04	11.2	44.1	5.95	3.6	11	6.4
C16:1	1.93		1.04	0.10							
C18:0	6.00	6.0	4.01	3.70	2.38	2,8	4.4	5.78	1.5	4	4.5
C18:1	66.58	72.2	76.40	78.27	68.00	74.53	39.0	66.96	61.6	53.4	63.8
C18:2	0.90	1.0	0.76	0.54	3.58	8.82	10.6	0.59	21.7	23.4	24.9
C18:3	0.20	-[b]	0.16	0.03	1.83	1.12	0.3	0.17	-	7.8	-[b]
C20:0	3.43	4.0	2.34	1.99	3.44	<0.01	0.2	3.77	1.4	-	-
C20:1	0.10	2.0	1.03	1.74	1.73	<0.01	-	2.12	-	-	-
C22:0	6.29	7.1	5.62	2.68	7.09	-	-	6.05	-	-	-
C22:1	0.16	0.12	0.65	0.07	-	-	-	-	0.2	-	-
C24.0	0.48	-	-	0.49	-	-	-	-	-	-	-
S:M:P	-	1	-		-		Trace			Trace	Trace
n_6:n_3											

MO= *Moringa oleifera* MS=*Moringa stenopetala* MP=*Mpringa PEREGRINA*

MC= *Moringa conconicense* [c] Eicosenoic acid

[a] Data from Gunstone and Harwod, 2007. The values constitute averages of numerous samples

[b] This may indicate traces (<1%) or absence of these fatty acids

[d] Data from Maleeha, *et. al.*, 2007

[e] Data from Umer, *et al.*, 2008

[f] Data from Lalas and Tsaknis, 2002

Table 1: Percentage (%) of fatty acids in the seed oil extracted from wild and cultivated trees of *Moringa peregrine* (Royal Scientific society, 2018)

	Fatty acid	Symbol	Wild trees	Cultivated trees
			(%)	(%)
1	Myristic	C14:0	0.07	0.08
2	Palmitic	C16:0	9.15	8.87
3	Palmitoleic	C16:1	1.73	1.72
4	Margaric	C17:0	0.13	0.11
5	Heptadecenoic	C17:1	0.08	0.06
6	Stearic	C18:0	3.52	3.91
7	Oleic	C18:1	78.52	77.99
8	Linoleic	C18:2	0.39	0.46
9	Linolenic	C18:3	0.02	0.02
10	Arachidic	C20:0	1.87	2.05
11	Gadoleic	C20:1	1.57	1.52
12	Behenic	C22:0	2.44	2.69
13	Erucic	C24:0	0.51	0.53

Tab. 2. Fatty acid composition [%] of the degummed oils. Values are means of triplicate determinations and standard deviation is given in parenthesis. P_1: Level of significant difference between methods of extraction. P2: Level of significant difference *Moringa stenopetala* vs. Virgin olive oil. P_3: Level of significant difference *M. stenopetala* vs. *M. oleifera*.

Fatty acid	Cold pressure	n-Hexane	Chloroform: methanol	P_1	Virgin olive oil	P_2	*M. oleifera* var. PKM1 (*Lalas, Tsaknis*, [2])			
							Cold pressure	n-Hexane	Chloroform: methanol	P_3
C8:0	0.04 (0.02)	0.03 (0.01)	0.02 (0.01)	NS	Not detected	0.05	0.04 (0.01)	0.03 (0.01)	0.03 (0.01)	NS
C14:0	0.10 (0.05)	0.11 (0.08)	0.12 (0.03)	NS	<0.01	0.05	0.13 (0.08)	0.13 (0.08)	0.13 (0.06)	NS
C16:0	6.01 (0.42)	6.21 (0.33)	5.98 (0.19)	NS	12.2 (0.76)	0.05	6.34 (0.41)	6.46 (0.32)	6.36 (0.25)	0.05
C16:1*cis* ω9	0.09 (0.07)	0.12 (0.04)	0.11 (0.08)	NS	1.12 (0.58)	0.05	0.10 (0.06)	0.09 (0.04)	0.09 (0.04)	NS
C16:1*cis* ω7	1.04 (0.71)	1.29 (0.97)	1.27 (0.66)	NS	Not detected	0.05	1.28 (0.87)	1.36 (0.84)	1.40 (0.82)	NS
C17:0	0.08 (0.04)	0.07 (0.05)	0.07 (0.06)	NS	<0.01	0.001	0.08 (0.02)	0.08 (0.02)	0.08 (0.02)	NS
C18:0	4.01 (0.87)	4.32 (0.58)	4.18 (0.33)	NS	2.90 (0.10)	0.05	5.70 (0.21)	5.88 (0.23)	5.74 (0.24)	0.05
C18:1†	76.40 (1.05)	74.61 (0.94)	74.52 (1.12)	NS	74.44 (0.69)	0.05	71.60 (0.73)	71.21 (0.69)	71.22 (0.70)	0.05
C18:2	0.76 (0.22)	0.77 (0.53)	0.75 (0.18)	NS	8.73 (0.54)	0.05	0.77 (0.38)	0.65 (0.32)	0.66 (0.33)	NS
C18:3	0.16 (0.08)	0.18 (0.04)	0.16 (0.09)	NS	1.02 (0.43)	0.05	0.20 (0.03)	0.18 (0.05)	0.17 (0.05)	NS
C20:0	2.34 (0.46)	2.58 (0.29)	2.52 (0.34)	NS	<0.01	0.05	3.52 (0.29)	3.62 (0.33)	3.60 (0.44)	0.05
C20:1	1.03 (0.27)	0.89 (0.17)	1.95 (0.74)	NS	<0.01	0.05	2.24 (0.26)	2.22 (0.26)	2.25 (0.20)	0.05
C22:0	5.62 (0.90)	6.01 (0.78)	5.87 (0.61)	NS	<0.01	0.05	6.21 (0.49)	6.41 (0.46)	6.28 (0.47)	0.05
C22:1*cis*	0.65 (0.20)	0.64 (0.11)	0.65 (0.30)	NS	Not detected	0.05	0.12 (0.07)	0.12 (0.07)	0.12 (0.08)	0.05
C26:0	1.47 (0.40)	1.59 (0.16)	1.57 (0.24)	NS	Not detected	0.05	1.21 (0.16)	1.18 (0.20)	1.23 (0.21)	0.05

† - Mixture of *cis* and *trans* C18:1, NS - not significant.

Tab. 3. Sterol composition (% of total sterols) of the degummed oils. Values are means of triplicate determinations and standard deviation is given in parenthesis. P_1: Level of significant difference between methods of extraction. P_2: Level of significant difference *Moringa stenopetala* vs. virgin olive oil. P_3: Level of significant difference *M. stenopetala* vs. *M. oleifera*.

Sterols by GLC	Cold pressure	n-Hexane	Chloroform: methanol	P_1	Virgin olive oil	P_2	*M. oleifera* var. PKM1 (*Lalas, Tsaknis*, [2])			
							Cold pressure	n-Hexane	Chloroform: methanol	P_3
Total sterols in oil [% w/w]	0.56 (0.02)	0.58 (0.01)	0.51 (0.02)	NS	0.66 (0.03)	0.05	0.52 (0.03)	0.56 (0.04)	0.48 (0.04)	NS
Cholesterol	0.11 (0.02)	0.10 (0.06)	0.13 (0.07)	NS	0.08 (0.02)	0.05	0.18 (0.04)	0.10 (0.02)	0.12 (0.03)	NS
Brassicasterol	0.03 (0.01)	0.05 (0.03)	0.07 (0.06)	NS	<0.1	0.05	0.06 (0.02)	0.05 (0.01)	0.05 (0.01)	NS
24, Methylene cholesterol	0.73 (0.15)	0.80 (0.21)	0.87 (0.22)	NS	Not detected	0.05	0.07 (0.01)	0.08 (0.01)	0.09 (0.01)	0.05
Campesterol	13.68 (0.93)	14.26 (0.55)	13.90 (0.73)	NS	3.11 (0.85)	0.05	15.81 (1.10)	15.29 (1.09)	14.60 (1.01)	NS
Campestanol	0.28 (0.11)	0.24 (0.09)	0.33 (0.43)	NS	0.40 (0.09)	0.05	0.36 (0.05)	0.33 (0.05)	0.33 (0.03)	NS
Stigmasterol	16.35 (1.18)	16.53 (0.97)	15.76 (1.25)	NS	0.54 (0.10)	0.05	23.10 (1.63)	23.08 (1.13)	22.50 (1.19)	0.05
Ergostadienol	0.22 (0.10)	0.34 (0.07)	0.26 (0.14)	NS	Not detected	0.05	0.30 (0.04)	0.35 (0.04)	0.36 (0.04)	NS
Clerosterol	1.15 (0.34)	1.43 (0.67)	1.60 (0.48)	NS	0.53 (0.22)	0.05	2.08 (0.12)	1.22 (0.09)	1.80 (0.09)	0.05
β-Sitosterol	52.19 (1.89)	51.60 (1.98)	51.48 (1.54)	NS	64.7 (4.15)	0.05	45.58 (3.66)	43.65 (2.79)	44.05 (3.02)	0.05
Stigmastanol	0.95 (0.38)	0.74 (0.22)	0.87 (0.19)	NS	0.38 (0.07)	0.05	0.76 (0.10)	0.64 (0.17)	0.74 (0.11)	0.05
Δ^5-Avenasterol	11.45 (1.23)	10.67 (1.55)	12.02 (0.94)	NS	17.33 (1.24)	0.05	8.46 (0.92)	11.61 (1.14)	10.43 (1.01)	0.05
$\Delta^{7,14}$-Stigmastadienol	Not detected	Not detected	Not detected	NS	Not detected	0.05	0.52 (0.22)	0.39 (0.10)	0.40 (0.09)	0.05
28, Isoavenasterol	0.98 (0.37)	1.37 (0.43)	1.11 (0.77)	NS	Not detected	0.05	0.27 (0.12)	0.25 (0.11)	0.40 (0.09)	0.05
$\Delta^{7,14}$-Stigmastanol	0.72 (0.22)	0.33 (0.12)	0.40 (0.08)	NS	<0.1	0.05	0.35 (0.14)	0.85 (0.28)	0.51 (0.18)	0.05
Δ^7-Avenasterol	1.01 (0.40)	1.18 (0.53)	1.11 (0.38)	NS	0.20 (0.07)	0.05	0.53 (0.07)	Not detected	1.15 (0.19)	0.05

NS - not significant

MORINGA CARBON SEQUESTRATION

Kwame Nkrumah University of Science & Technology, Kumasi, Ghana

- The moringa plant absorbs CO2 twenty times more than the average plant
- Increasing moringa plantations from 100,000 ha to 1 million ha could potentially sequester .4 giga tonnes of CO2 annually
- Public private partnership model could easily make this possible
- The PPP mpdel on moringa out grower systems for social benefit need to be tested
- Climate change and adaptability measures; positioning the small scale farmer in Africa to play meaningful role in low carbon emission,
- Leading better nutrition of local people and reduced poverty

COLD PRESSED OIL AND SEED CAKE


A
B
C
D
E
F

SUPERCRITICAL CO_2 OIL

Proximate Analysis Of Moringa Seed And Defatted Meal

Sample	Main chemical compositions				
	Moisture	Crude Protein	Fat	Ash	Total Sugars
Moringa seed	2.90	32.50	36.80	4.00	3.40
Deffated (Cold Press)	3.31	50.16	26.40	4.60	3.40
Defatted (SCFE)	3.20	52.74	11.50	5.00	4.30

Table 1 Moringa seed cake in comparison with major oil seed cakes.

CP= crude protein

	CP %	Carbohydrates %	Ash	Fat %	Reference
Moringa seed cake	52.74	4.30	5.00	11.50	*Present work*
Soybean oil cake	51.80	23.60	7.30	0.90	Castro, *et. al.*, 2007
Rapeseed oil cake	42.80	32.20	7.00	4.10	Bell, 1984
Cottonseed oil cake	41.50	27.00	6.46	5.75	Briggs & Heller, 1942
Groundnut oil cake	45.60	14.10	5.62	2.47	Batal, *et. al.*,2005
Sunflower seed cake	35.60	23.00	7.36	1.68	Villamide & San Juan, 1998
Palm kernel oil cake	17.50	45.50	4.80	7.40	Carvalho, *et. al.*, 2006
Sesame oil cake	48.20	21.00	12.60	2.30	Yamauci *et. al.*, 2006
Linseed	33.20	36.00	5.40	2.80	Loosli, *et. al.*, 1960
Sunflower oil cake	44.00	20.10	7.20	5.90	Lyon, *et. al.*, 1979
Copra cake	20.90	42.40	5.50	8.00	Thampan, 1975
Olive oil	4.99	10.70	2.36	8.72	Vlyssides, *et. al.*, 2004

MORINGA CARBON & SEQUESTRATION

Kwame Nkrumah University of Science & Technology,
Kumasi, Ghana

Moringa is fast growing, versatile and well adapted to growing in adverse conditions of at least 400 mm of rain per annum where many plants would not be able to grow.

The moringa plant absorbs carbon dioxide twenty times (20x) higher than that of general vegetation and fifty times (50x) higher when compared to the Japanese cedar tree. (Villafuerte, and Villafurte-Abonal 2009).

If we expanded *M. oleifera* from one hundred thousand (100,000) hectares worldwide to one million (1,000,000) hectares, that would equate to five (5) giga tonnes of carbon dioxide being sequestered.

Therefore, growing more moringa will absorb more carbon dioxide from the atmosphere, limiting the world's greenhouse gas emission and slow the progress of global warming.

One mature moringa tree (3 years old) can produce

- 15,000 to 25,000 seeds per year and
- a plantation can produce 3000 kg of seeds per hectare.

This is equivalent to

- 900 kg oil per hectare (i.e. 30%) and
- is comparable to soybean which needs yearly cropping and
- yields an average of 3000 kg seeds per hectare with only 20% oil yield (Mohammed, *et al.*, (2003).

COST OF ESTABLISHING & REVENUE OF 1 HECTARE OF MORINGA SEED PLANTATION

Kwame Nkrumah University of Science & Technology, Kumasi, Ghana

Cost of 1 moringa Seeds	10 p
Cost of Polybags for nursery	20p
Labour Cost of Nursery	50p
Cost of Transportation & seedling transplanting	70p
Maintenance cost per year is	2.00 gh cedis

(30 p for weeding and pruning per quarter; 20 p for irrigation, fertilization & pest control per quarter)

Sub-total of production cost of 1 moringa tree is	3.50 / plant
5% contingency	0.175
Total production cost of 1 moringa tree is	3.675 gh cedis

At a spacing of 3 x 3 meters we have 1,111 plants per hectare.

Total Production cost per **hectare** (3.675 x 1,111)	**4,082.925 gh cedis**
Expected output is 3,000 kg per year (3yrs old)	3,000 kg
Average current farm gate price of moringa seeds is	5 cedis /kg
Gross revenue per hectare @ farm gate	15,000 cedis
Net revenue per hectare @ farm gate	**10,918 gh cedis**
	3,119.42 US$

There have been times in human history when tens of thousands of vegetables, cereals, etc were used as food but today we rely on just a few cereals.

After roughly 10,000 years of progressive agricultural civilization, Seventy percent of the world's food supply comes from just three grains —corn, wheat, rice ;

Eighty percent of our plant-based food intake comes from just twelve plants—eight grains and four tubers (Nierenberg, 2011).

Out of 250,000 identified plant species worldwide that only 30 species provide 95 percent of our global food energy needs? And that only three of these crops – wheat, maize and rice – provide half of the world’s food?

With severe weather extremes and other risks to global food security, many agricultural experts agree that global cropping systems should be as diversified as possible.

As small-scale farms are particularly vulnerable to climatic and economic instability, underutilized crops may be key to their resilience.

Underutilized crops are those with “underexploited potential for contributing to food security, nutrition, health, income generation and environmental services.”

The main-streaming and re-integration of *M. oleifera* into the human food chain will contribute to food security, biodiversity utilization, climate resilient agriculture, generate a huge industry while improving the health and wellbeing of the general population.

This emerging moringa trade needs to be supported to take up its center stage position as a major income earner in many developing economies.

Strong policies, research and market development strategies are needed to help strategically develop moringa and other crops as natural resources.

THANK YOU

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