Nutritional and Functional Properties of Moringa Leaves – From Germplasm, to Plant to Food, to Health

Moringa and Other Highly Nutritious Plant Resources: Strategies, Standards and Markets for a Better Impact on Nutrition in Africa

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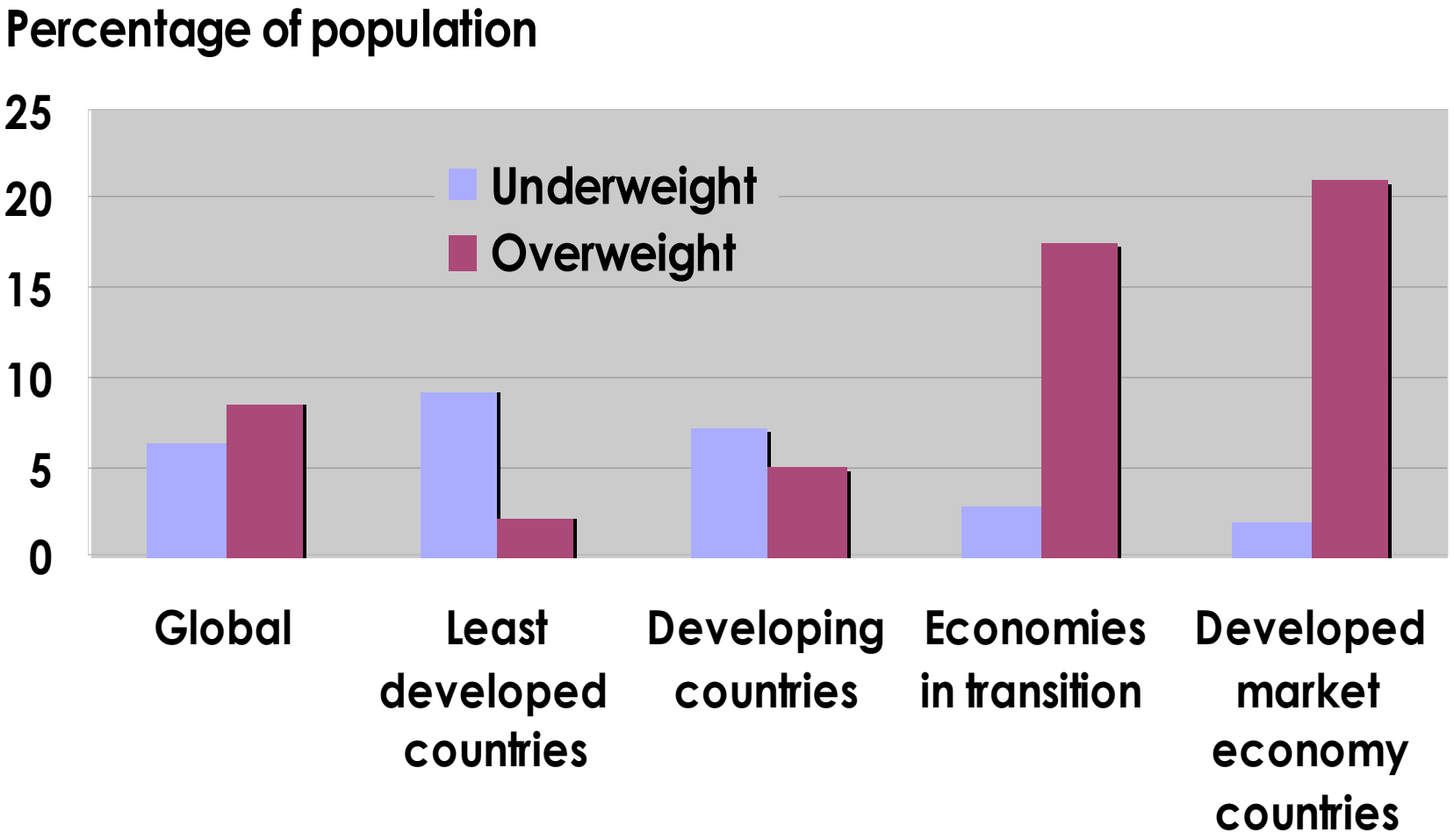
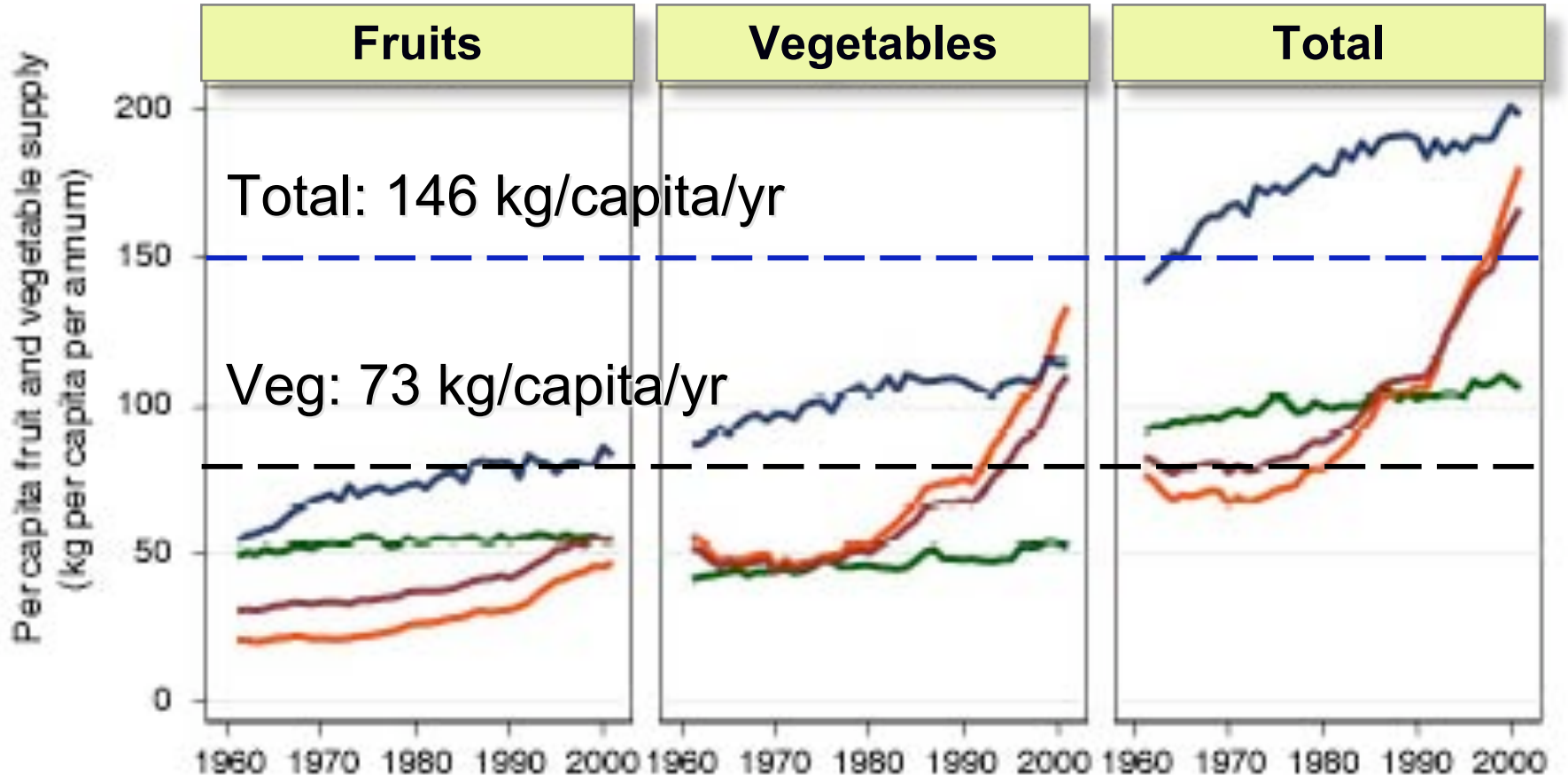
AVRDC – The World Vegetable Center

Coexist of underweight and overweight: overweight is on the rise



Source: FAO, focus 2004

Per capita fruit and vegetable supply (kg/person/year)



[1]Upward trend of vegetables largely influenced by changes in China

Source: FAOSTAT data, 2004

AVRDC multi-strategies to improved nutrition and health

Consumption x **Nutrient/ bioactive compound density** x **Bio-availability**

- Increased vegetable availability and consumption
- Improved nutrient and phytochemical density
- Enhanced iron bioavailability

= **Health outcome**

- Assessing the benefits from the consumption of vegetables on health and overall economic development.

AVRDC Vegetable Genetic Resources

- The most diverse collection of vegetable germplasm in the world.
- Contains about 55,000 accessions of 334 different species from 151 countries.
- More than 300,000 seed samples distributed to researchers in 180 countries over 30 years

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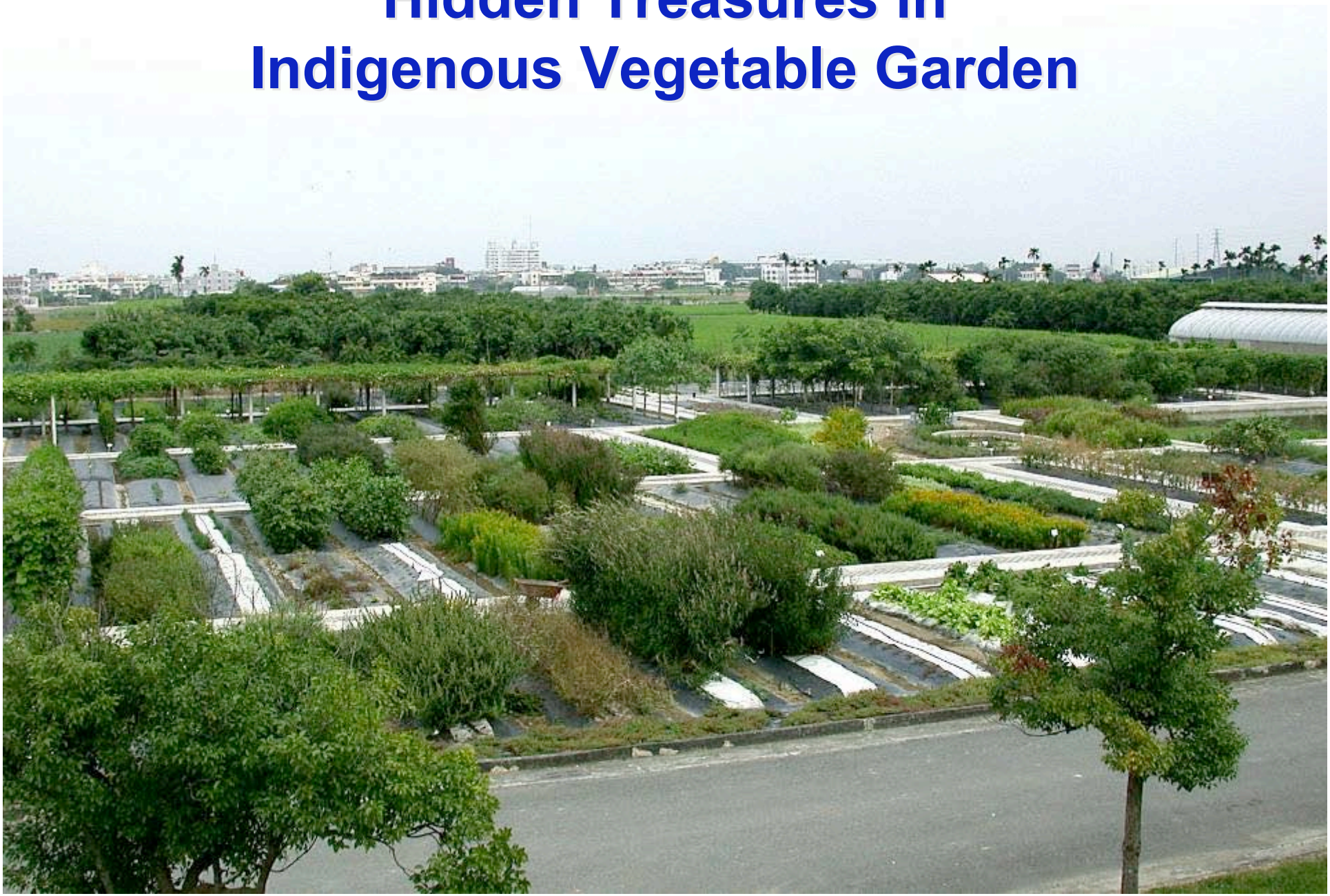
Hidden Treasures in Indigenous Vegetable Garden

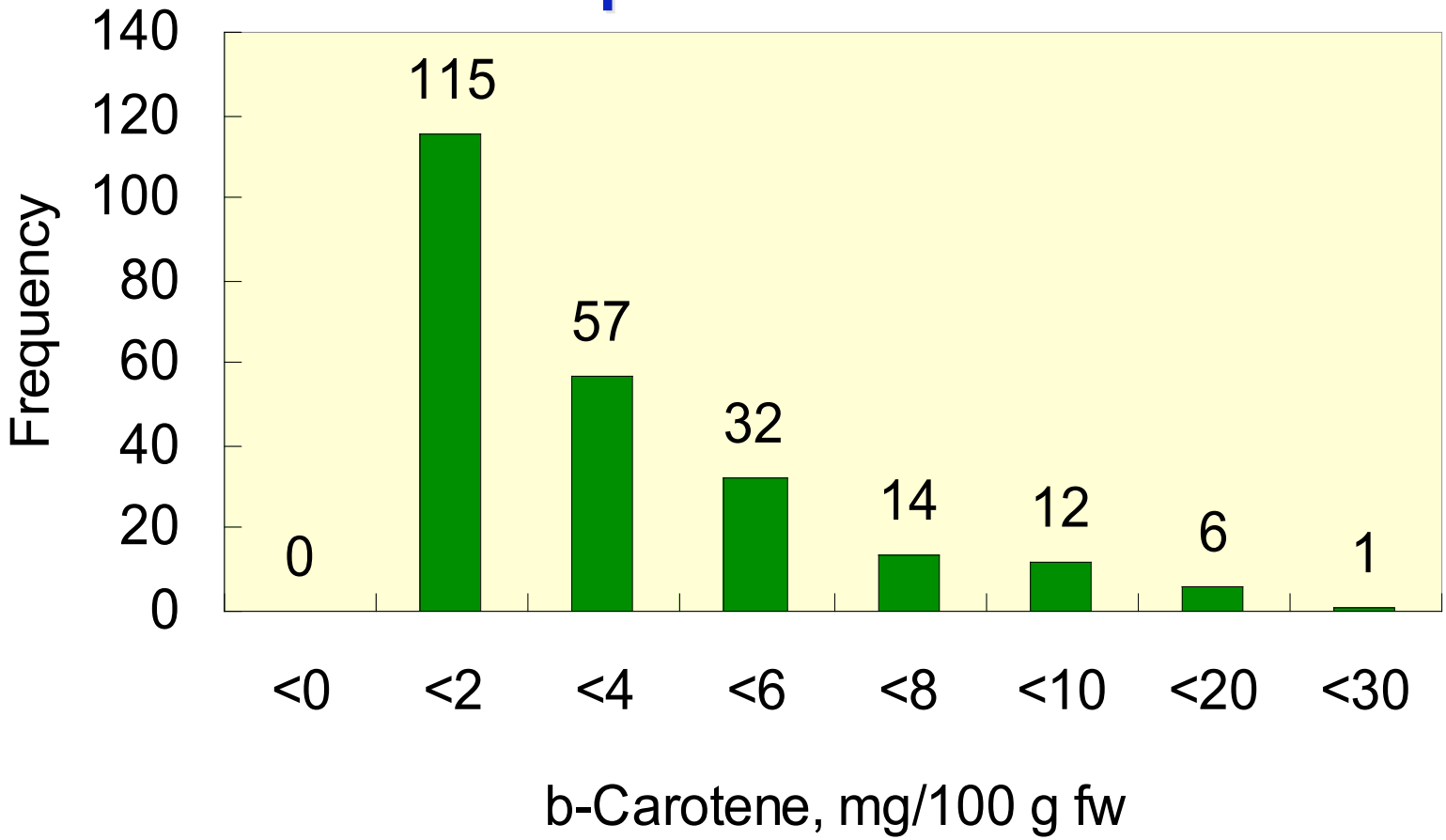


Nutrient Content Ranges

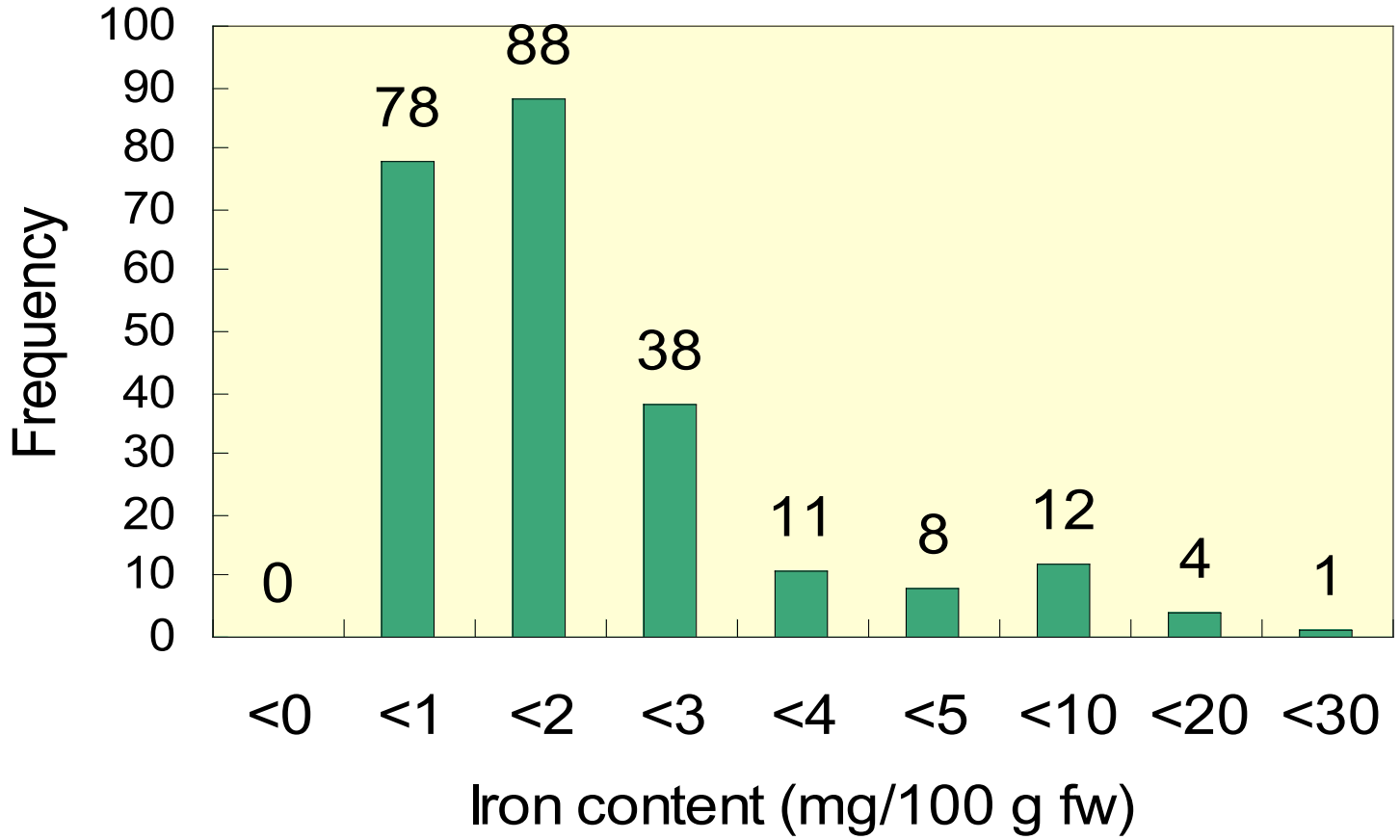
In 100 g FW	*N*	*Min*	*Max*	*Mean*	*SD*
Protein, g	243	0.2	10	3	1.6
β-carotene, mg	241	0.0	22	3.1	3.3
Vit. C, mg	243	1.1	353	70	77
Vit. E, mg	243	0.0	71	2.6	5.6
Folates, μg	90	2.8	175	51	40
Ca, mg	243	2	744	121	136
Fe, mg	243	0.2	26	2.1	2.6
Zn, mg	27	0.17	1.24	0.49	0.24
Total phenol, mg	241	17	12,070	444	940
AOA, TE	243	0.63	82,170	1383	5648

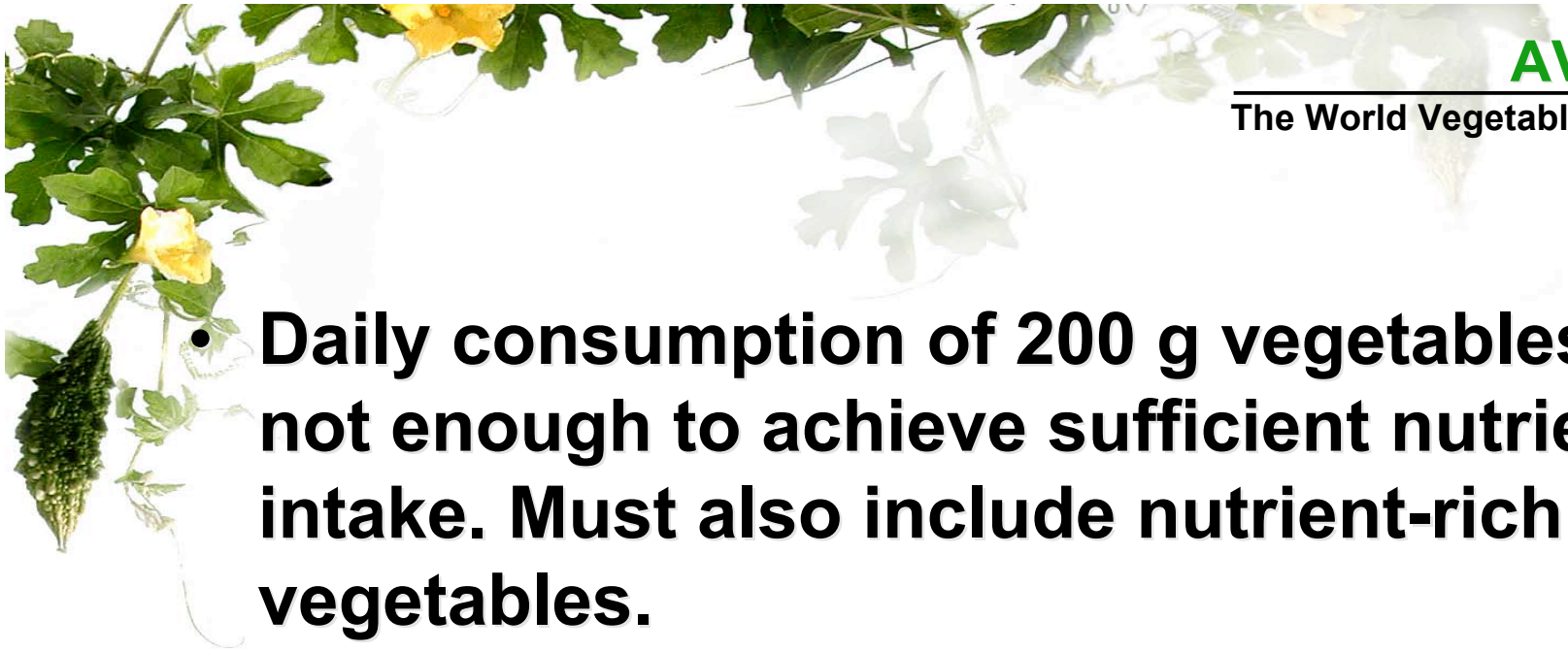
Specie no.: ~120

Vegetable distribution for β-carotene



Vegetable distribution for Iron





- **Daily consumption of 200 g vegetables is not enough to achieve sufficient nutrient intake. Must also include nutrient-rich vegetables.**
- **Nutrient-rich vegetables are underutilized and merit greater attention. Additional investigations will likely uncover even more nutritional value in these treasures**

Criteria for vegetable selection

Criteria	Chinese cedar	Moringa leaves	Sweetpotato leaves	Amaranth
Vitamin A	****	*****	***	***
Iron	***	****	****	****
Fresh market	***	***	*****	*****
Postharvest handling	****	**	****	****
Processing	****	****	*	*
Health promoting factors	****	****	****	***
Phytochemicals	*****	****	***	***
Low input	****	*****	****	****
Tropically grown	**	*****	*****	*****

Nutritional and Antioxidant Properties of Moringa Leaves

from Germplasm

to Plant

to Food

to Health

From Germplasm

Nutrient and phytochemical contents among four Moringa species

Moringa drouhardii

Moringa oleifera

Moringa stenopetala

Moringa peregrina

Moringa samples

Sample number	Species	Tree age	Part for analyses	Groups	Origin
MO27	*oleifera*	3 yr	Leaf, stem, seed	Slender tree	India
MO28	*stenopetala*	3 yr	Leaf, stem	Bottle tree	Kenya, Ethiopia
MO30	*peregrina*	3 yr	Leaf, stem	Slender tree	Arabia, red sea area
MO31	*drouhardii*	3 yr	Leaf, stem	Bottle tree	Madagascar

Nutrients in four Moringa species

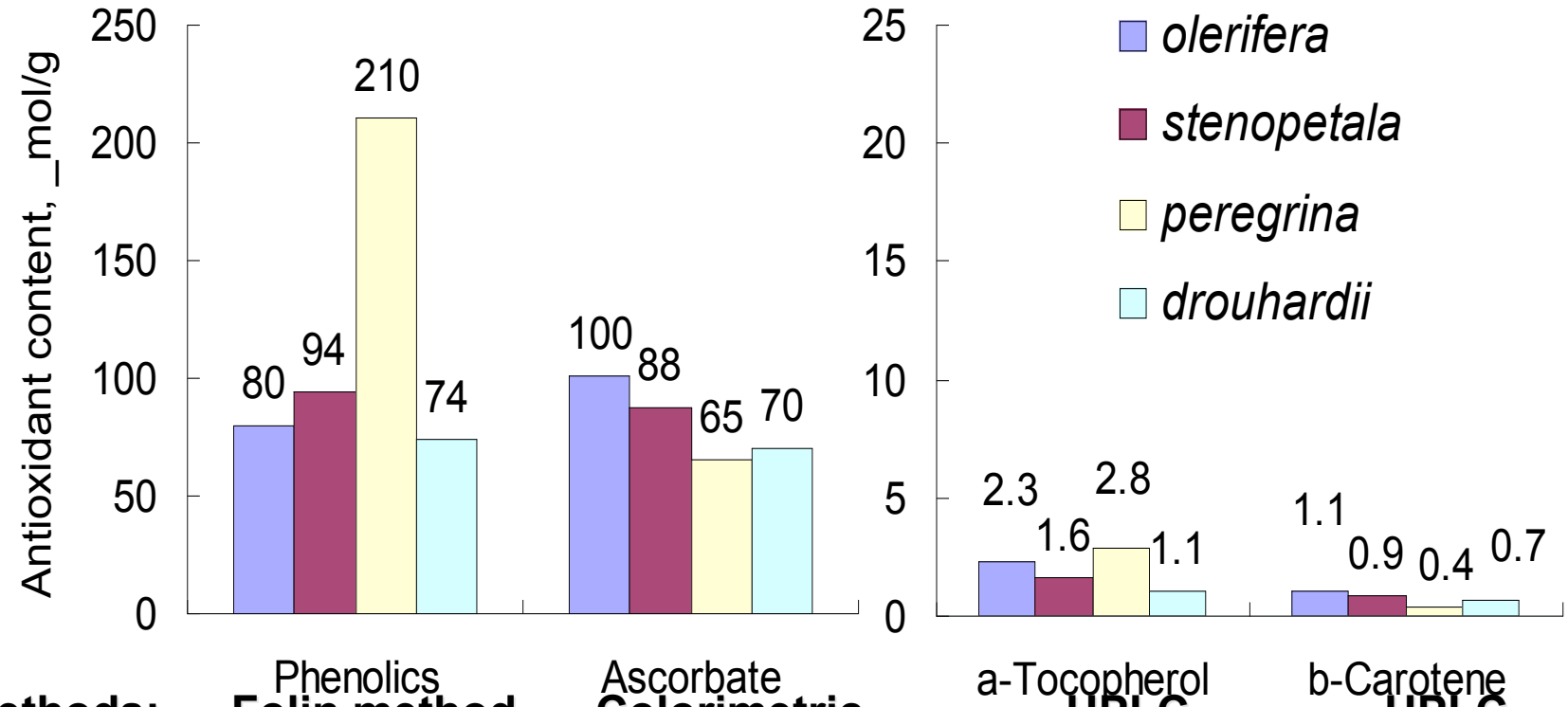
100 g fresh mature leaves

Specie	DM	Prot. g	β-Car mg	Vit C mg	Vit E mg	Iron mg	Ca mg
olerifera	24	5.7	15	459	25	9.2	638
stenopetala	24	5.8	13	400	18	5.4	711
peregrina	21	2.9	5	264	28	5.6	458
drouhardii	29	5.0	11	388	14	8.7	745

- No stachyose or raffinose were detected in leaves
- Low in oxalate (~25 mg/100g, only 5% of oxalate in spinach)

Dominant Antioxidants in Moringa leaves

(µmole/g on dry weight basis)



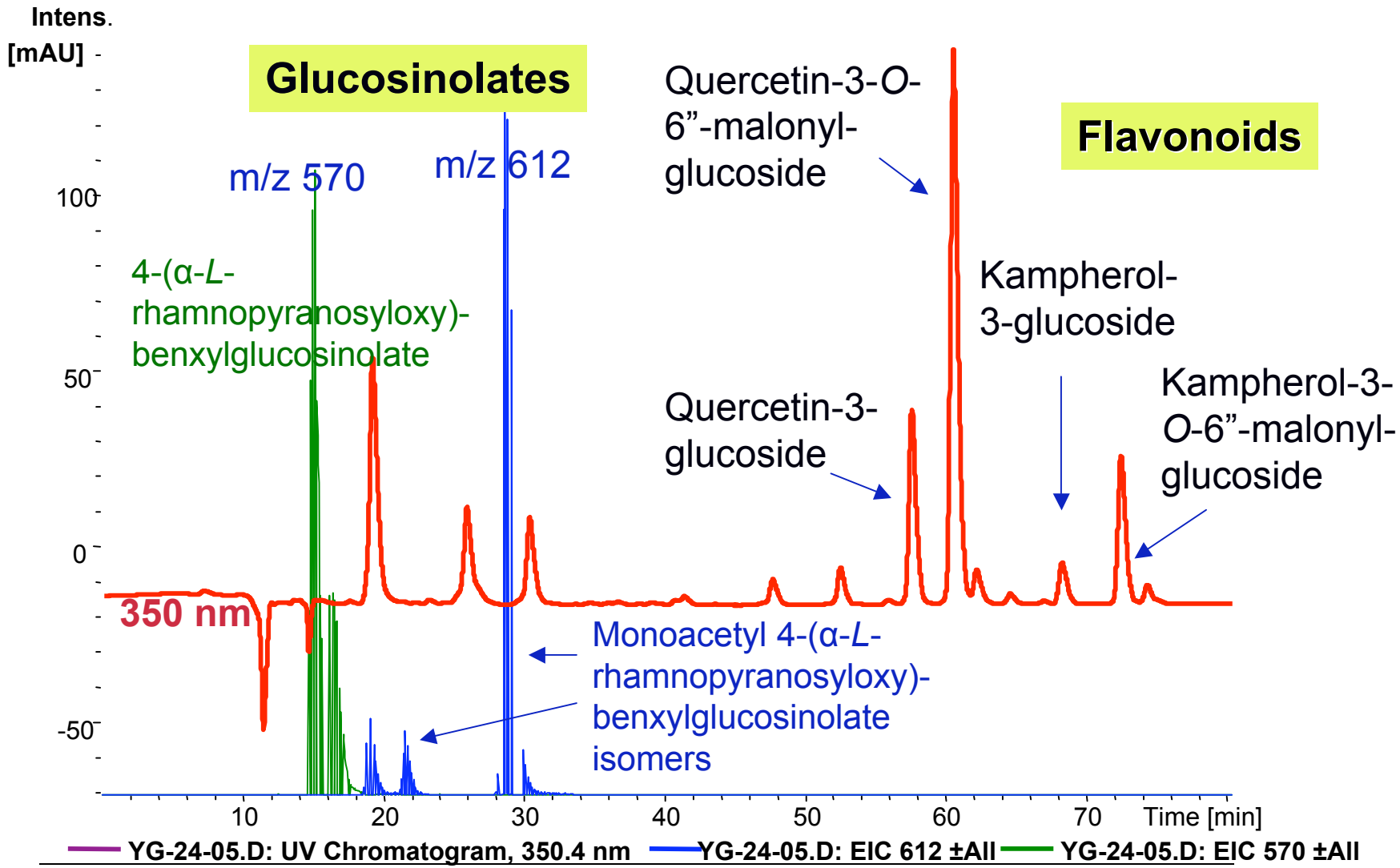
Methods: **Folin method,** chlorogenic acid equivalents

Colorimetric, measuring total oxidized ascorbate

HPLC

HPLC

Phytochemicals in *Moringa oleifera*



Conclusion 1

- **High nutrients, antioxidants and glucosinolates, and low oxalate contents are common features of the four M. species.**
- ***M. peregrina* was the uppermost for antioxidant; *M. oleifera* has the highest nutrient values among the four.**

To Plants

Nutrient and phytochemical contents in Moringa leaves as affected by accession, harvesting season and leaf stage

Effects of variety, leaf type and season on nutrient and phytochemical contents

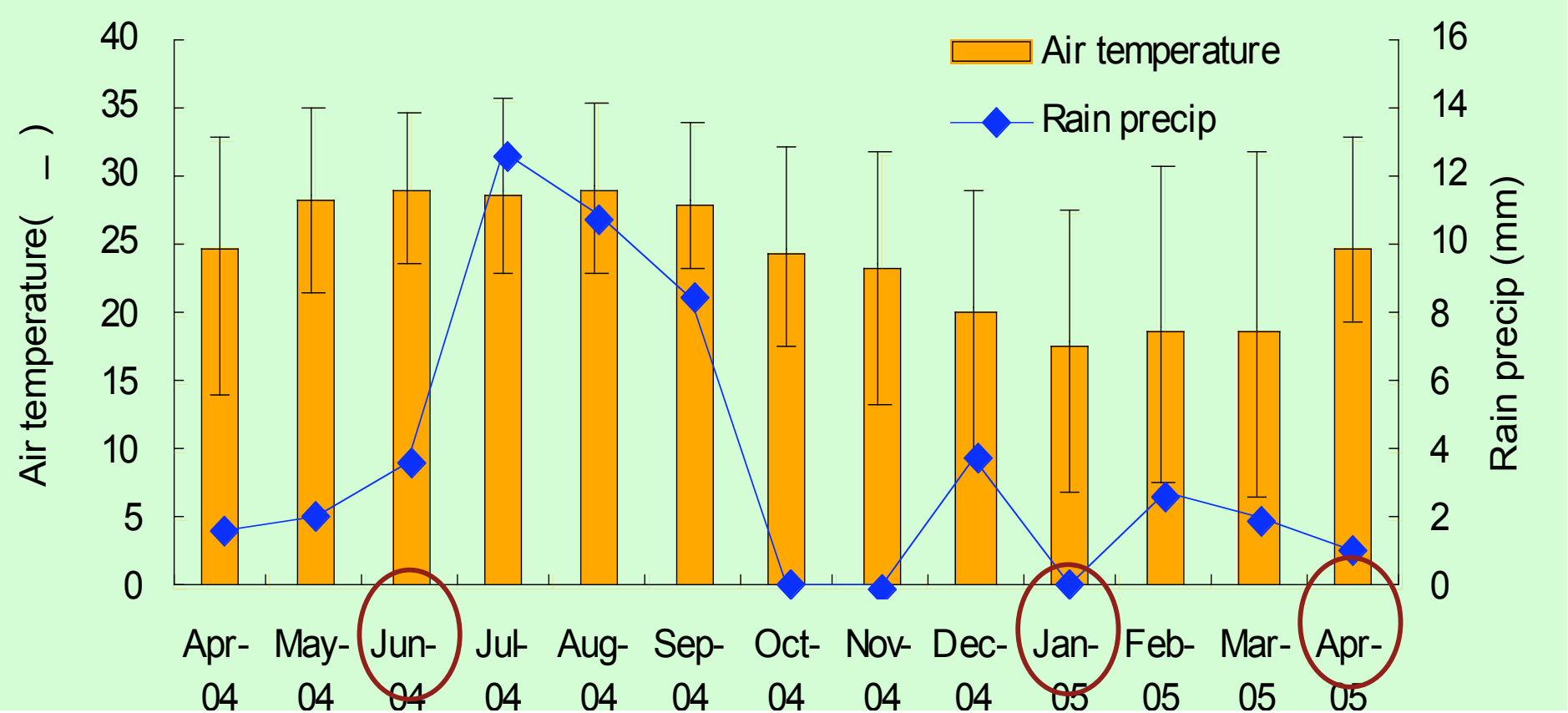
- **Experimental design**
  - **RCBD**
  - **Factors:**
    - **Variety: 10 *M. oleifera* accessions, 3 field replications**
    - **Leaf type: mature, young shoots**
    - **Harvesting season: hot-wet (June), cool-dry (Jan), spring (April)**
- **Analyses:**
  - **Protein, 3 vitamins, 2 minerals, phenolics, antioxidant activity (AOA)**

High density planting and pruning enable convenient and continuous harvests of young shoots

Harvesting

Young shoots grows quickly after the harvest

Air temperature and rain fall



Nutritional values of mature moringa leaves for three harvests

100 g FW	*June 2004 (Summer)*	*January 2005 (Winter)*	*April 2005(Spring)*
	Mature leaves		
Dry matter, g	23.8 ± 0.9 a	21.4 ± 0.7.b	21.4 ± 1.5 b
Protein, g	7.59 ± 0.35 a	6.59 ± 0.30 b	6.46 ± 0.89 b
Fiber, g	1.83 ± 0.16 b	1.93 ± 0.13 a	1.47 ± 0.11 c
Sugars, g	3.17 ± 0.41 a	3.04 ± 0.22 a	2.59 ± 0.44 b
Calcium, mg	434 ± 66 b	448 ± 48 b	481 ± 67 a
Iron, mg	6.24 ± 0.84 b	9.73 ± 1.00 a	4.10 ± 2.35 c
β-carotene	20.1 ± 1.8 a	7.8 ± 0.7 c	13.8 ± 0.9 b
Vitamin C	244 ± 18 b	320 ± 28 a	206 ± 21 c
Vitamin E	18.1 ± 3.6 a	17.4 ± 2.6 a	14.8 ± 2.3 b
AOA, µmol TE	4380 ± 862 a	2341 ± 205 b	4166 ± 1211 a
Phenolics, mg	558 ± 70 c	802 ± 54 a	681 ± 51 b

Nutritional values of moringa young shoots for three harvests

Components.	*June 2004 (Summer)*	*January 2005 (Winter)*	*April (Spring)*
	Young shoots		
Dry matter, g	**17.7 ± 1.5 a**	**15.4 ± 1.7 b**	**12.2 ± 1.1 c**
Protein, g	**5.33 ± 0.46 a**	**4.03 ± 0.57 b**	**3.48 ± 0.35 c**
Fiber, g	**1.59 ± 0.13 a**	**1.39 ± 0.16 b**	**1.43 ± 0.17 b**
Sugars, g	**2.52 ± 0.34 a**	**2.19 ± 0.28 b**	**1.88 ± 0.34 c**
Calcium, mg	**88 ± 20**	**84 ± 49**	**74 ± 9**
Iron, mg	**2.86 ± 1.08 b**	**4.22 ± 1.36 a**	**1.40 ± 0.34 c**
β-carotene	**6.96 ± 1.15 a**	**2.75 ± 1.00 b**	**2.56 ± 0.58 b**
Vitamin C	**256 ± 25 b**	**294 ± 35 a**	**183 ± 21 c**
Vitamin E	**6.09 ± 1.76 a**	**4.08 ± 1.60 b**	**2.86 ± 0.45 c**
AOA, µmol TE	**3381 ± 449 a**	**2223 ± 381 b**	**1307 ± 219 c**
Phenolics, mg	**552 ± 68 b**	**731 ± 100 a**	**461 ± 40 c**

Conclusion 2

- **Variation among 10 *M. oleifera* accessions for nutrient contents was small so breeding for higher nutrient content not worthwhile. Varietal selection should focus on horticultural traits.**
- **Mature leaves were more nutritious than young shoots and could be quickly dried with minimum nutrient loss; however, young shoots exhibited better eating quality and more acceptable for the fresh market.**
- **Seasonal effects caused 1.5 – 3x content variation for vitamin A, iron and antioxidants in moringa leaves; higher vitamin A was obtained in hot-wet season while higher iron and vitamin C were found in cool-dry.**

to Food

Nutrient and phytochemical contents in Moringa leaves as affected by processing temperature and simulated gastrointestinal digestion

Young shoots for fresh markets in Taiwan

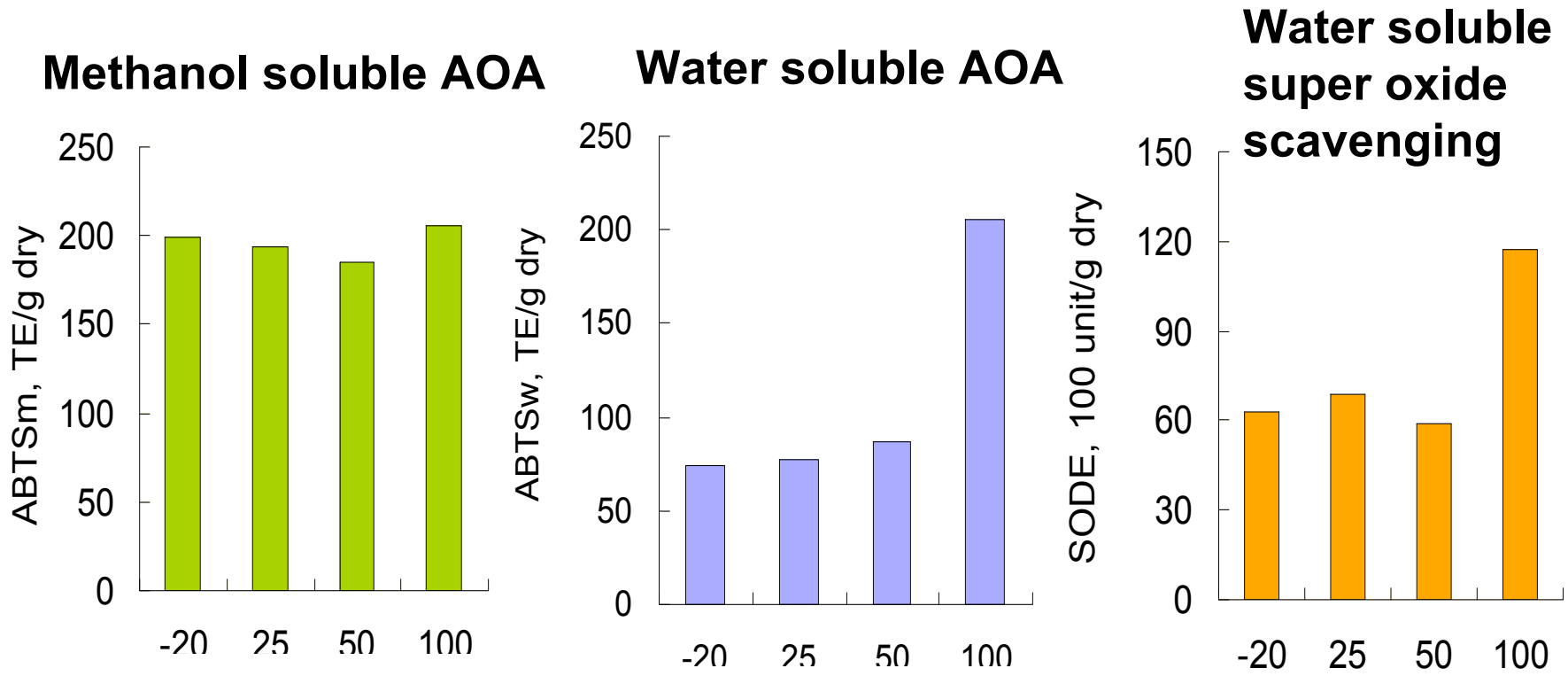
Mature leaves for commercial products: Leaf extracts and tea bags sold in Taiwan

50°C oven dried moringa powder for nutritional analysis and animal studies

Mild-heat drying maintained most nutrients/ phytochemicals in moringa leaves

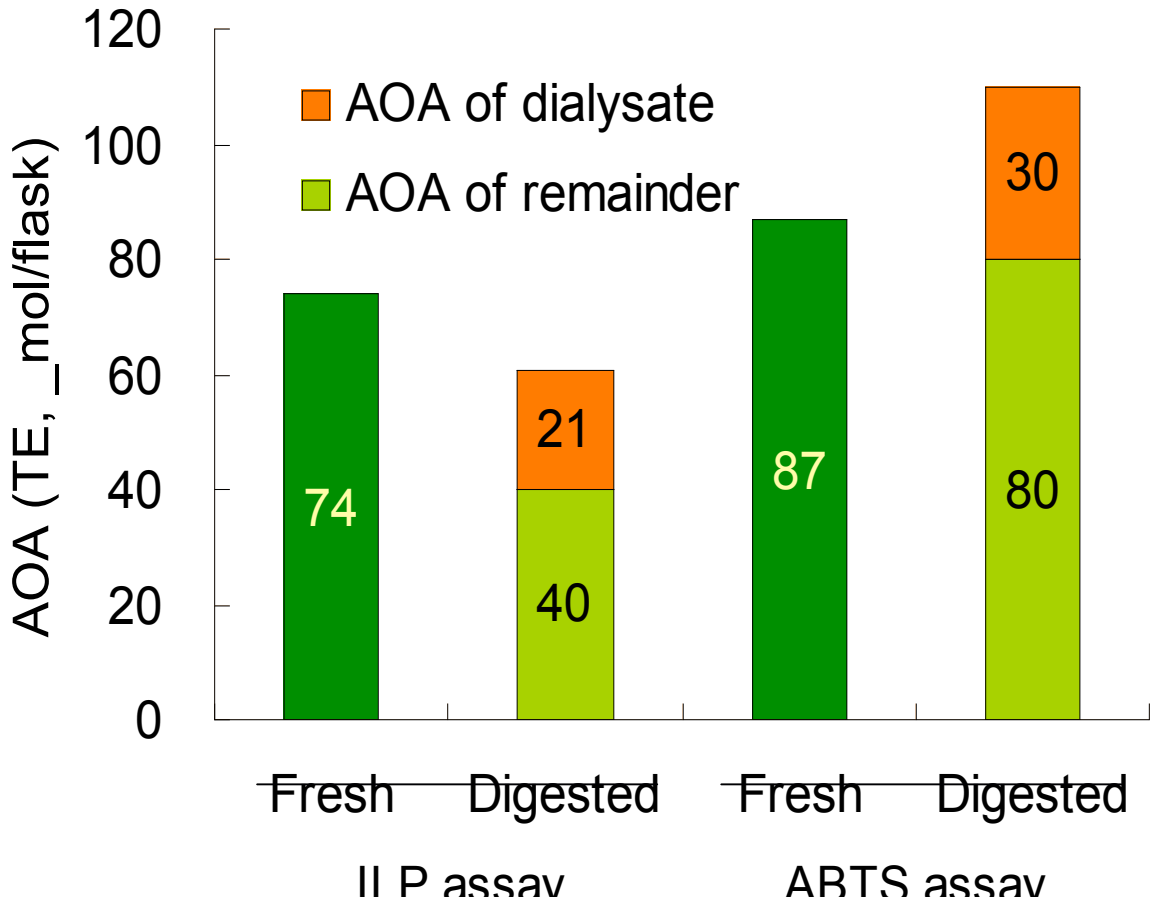
Per 100 g DW	Freeze dry	50°C dry
Protein, g	28	28
Fiber, g	8	8
β-Carotene, mg	154	110
Vitamin C, mg	582	157
Tocopherols, mg	169	165
Calcium, mg	1760	1670
Iron, mg	20	21
Polyphenols, g	3	3
Glucosinolates, mmol	8.6	9.9
AOA, mmol TE	15.4	17.3

Temperature effect on antioxidant activities (AOA) of *Moringa oleifera* leaves

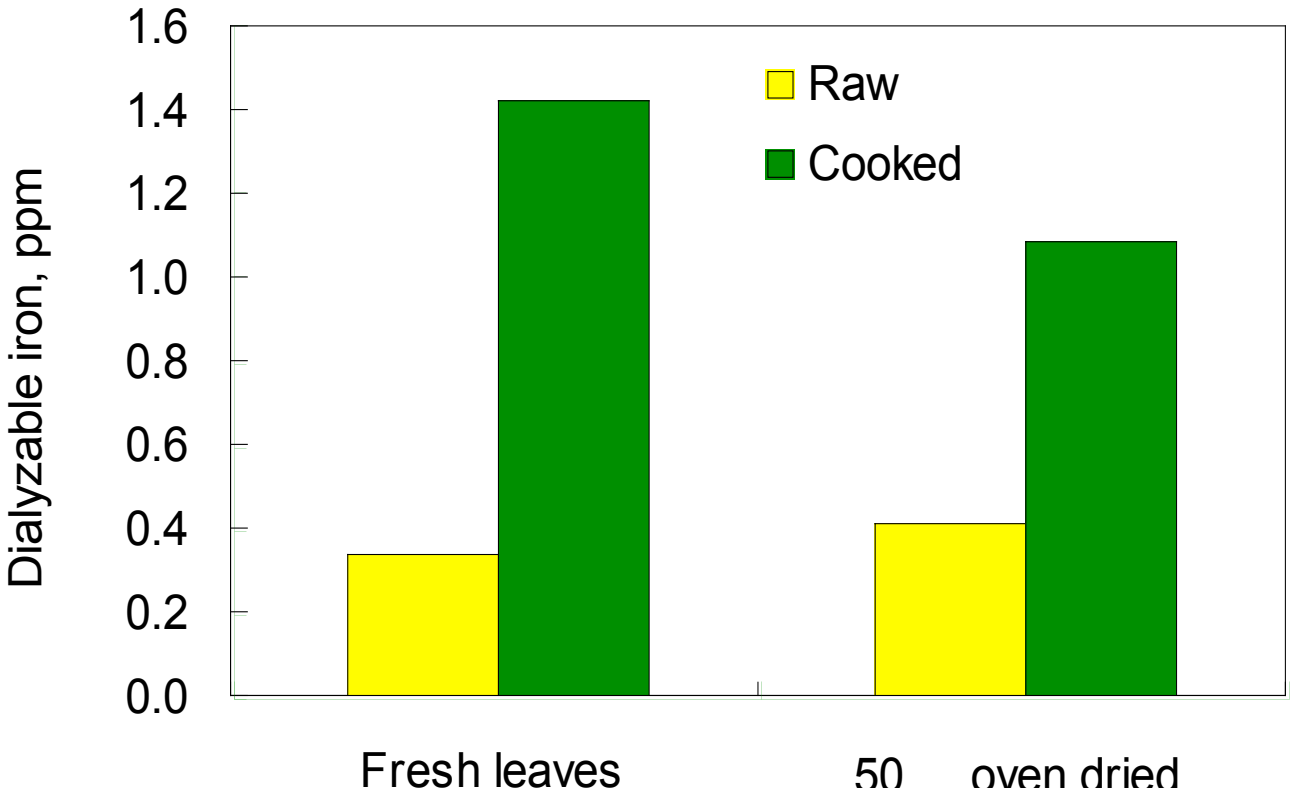


Treatments			
Freezing	Fresh	Mild heat	Boiling
-20°C / 4hr	RT, 25°C	50°C/10 min	100°C/10 min

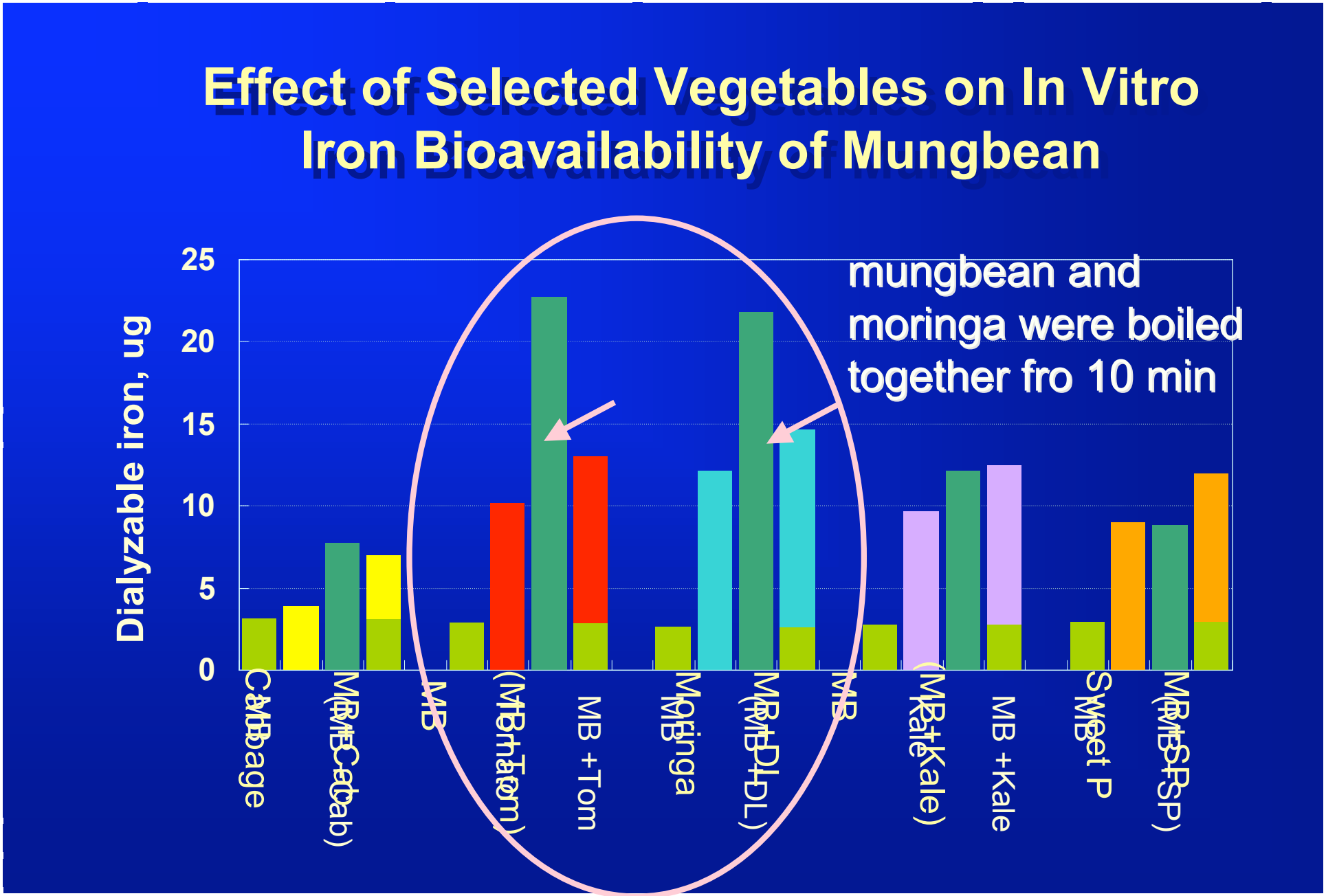
AOA changes before and after simulated digestion



In Vitro Iron bioavailability of Moringa leaves



Effect of Selected Vegetables on In Vitro Iron Bioavailability of Mungbean



MB: mung bean, Cab: cabbage, Tom: tomato, DL: drumstick leaves (Moringa), SP: sweet pepper

Conclusion 3

- Boiling Moringa leaves in water enhanced aqueous AOA, and the AOA was maintained after simulated digestion
- Cooking Moringa leaves increased available iron and raised total available iron of mixtures with mungbean.
- Mild-heat drying maintained most nutrients/ phytochemicals in Moringa leaves and provides a way for long term preservation and continuous nutrient/antioxidant supply

to Health

- As dietary micronutrients and antioxidants for human use
- Added to fodder for livestock production

Moringa leaves:

- as a micronutrients and antioxidants in diets for human use
- added to fodder as a potential bioceutical agent to substitute for antibiotics in livestock (broiler chicken) production

Immuno-modulation activity of dried morinag powder in diet for human use

- **Intervention with a diet containing 5% moringa powder was investigated using a rat model and compared to a 5% common cabbage diet, and a nutrient-sufficient diet without vegetable.**
- **The preliminary results after 3 weeks indicated that the moringa diet reduced blood triglycerides, enhanced immune response due to increased peripheral and splenocyte T-cell proliferations.**

Conclusion 4

- The study implies the consumption of moringa enhances the immune response of nutrient sufficient subjects.
- In addition, consumption of nutrient and phytochemical-rich vegetables, like moringa, leads to a better immune response compared to consumption of vegetables that are rich in fiber but lower in nutrient or phytochemical content, like common cabbage.
- Moringa should be promoted for greater consumption to improve nutrition and strengthen immune functions.

Moringa dishes

Acknowledgments

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Moringa Oleifera Tree