# 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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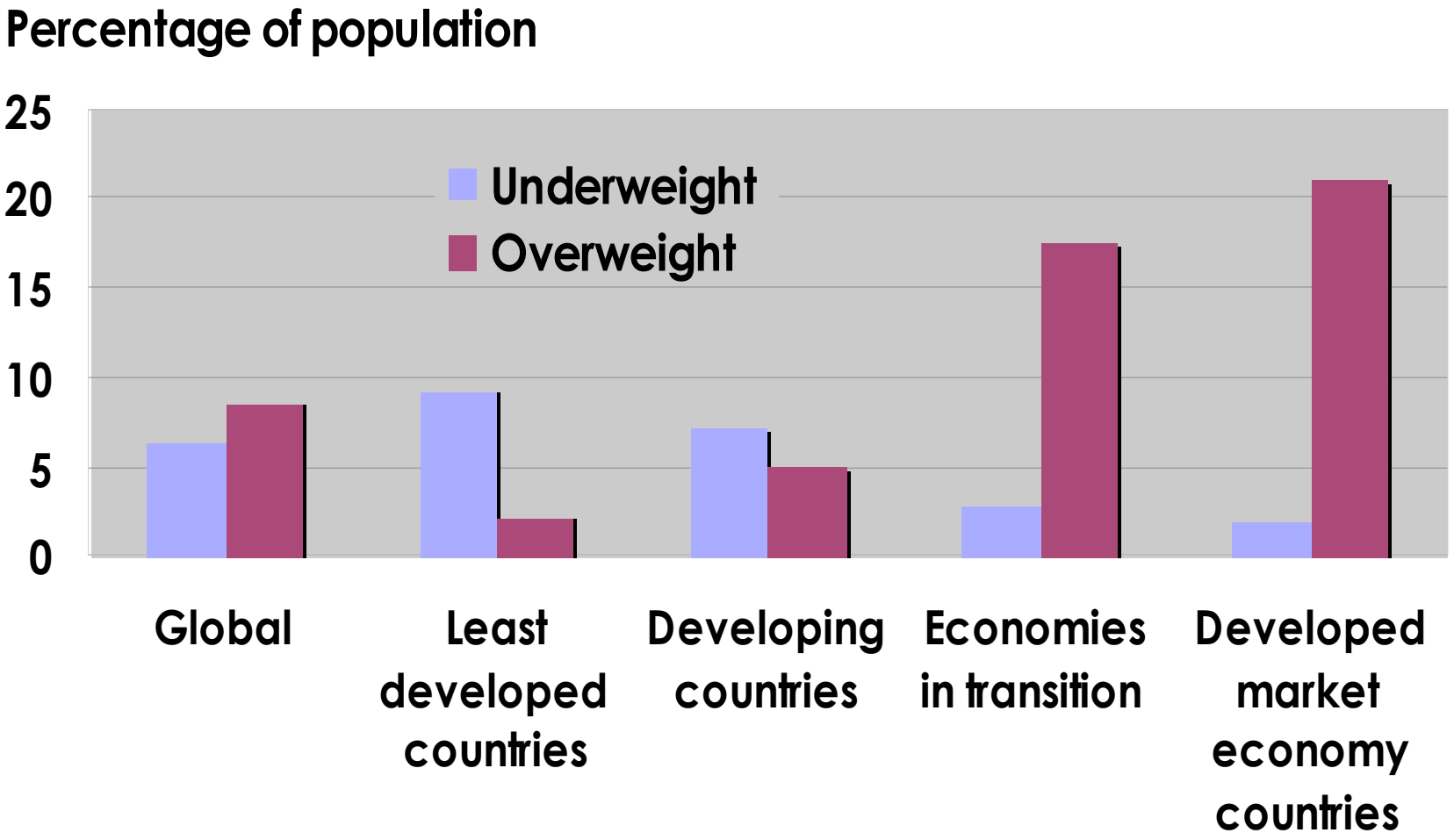
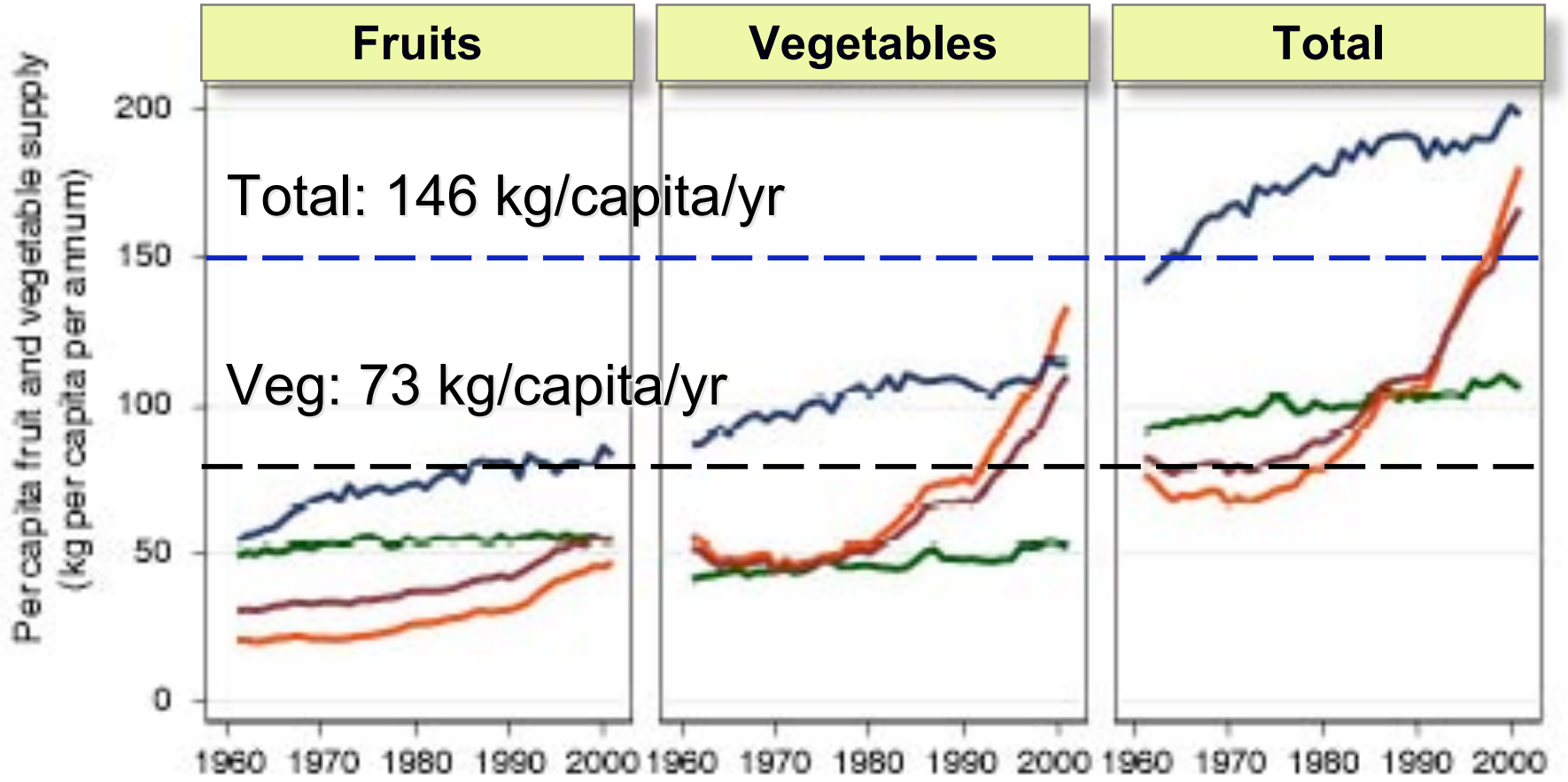
# Coexist of underweight and overweight: overweight is on the rise




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**

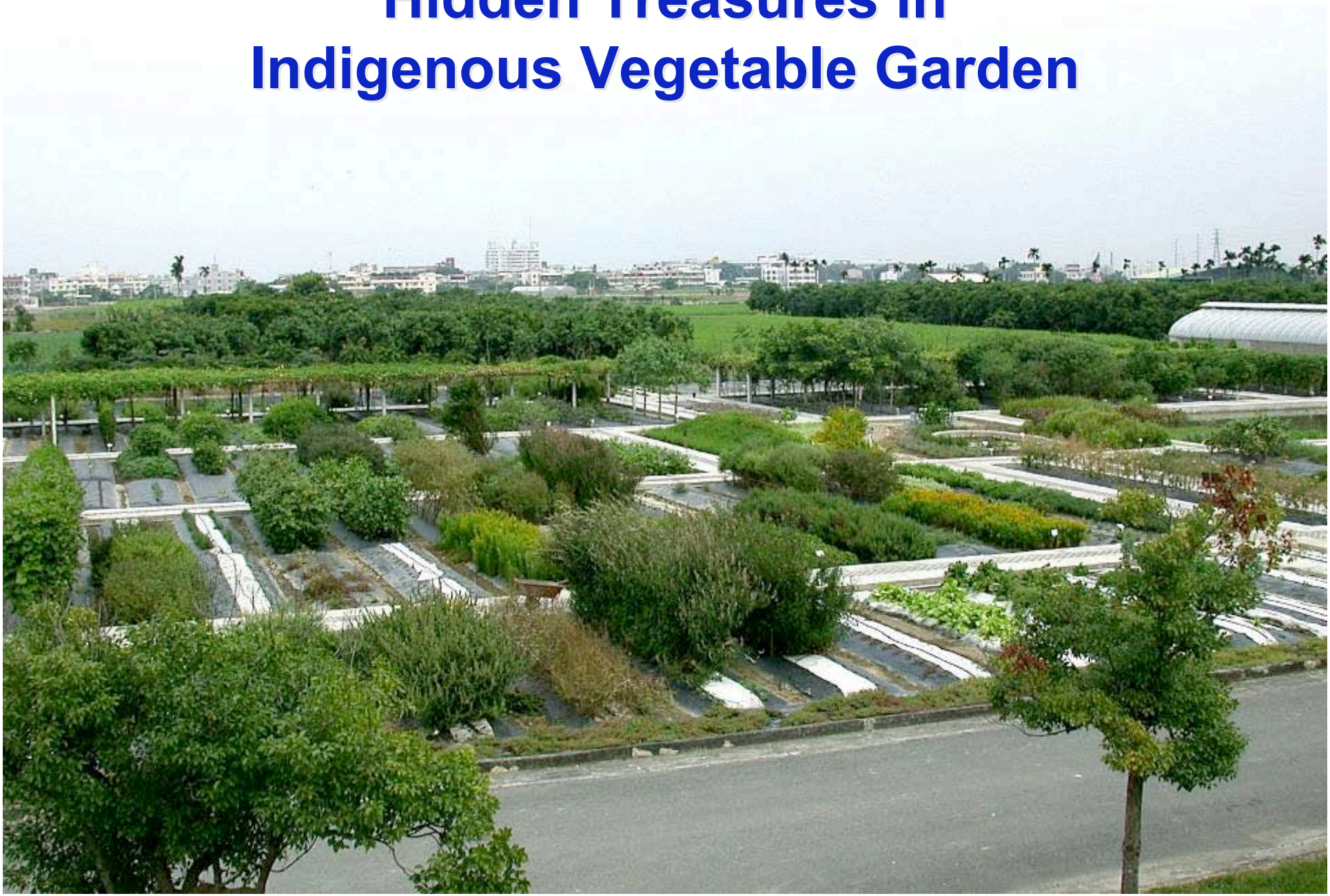
- Assessing the benefits from the consumption of vegetables on health and overall economic development.

# 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

Moringa and other highly nutritious plant resources: Strategies, standards and markets for a better impact on nutrition in Africa. Accra, Ghana, November 16-18, 2006

# Hidden Treasures in Indigenous Vegetable Garden

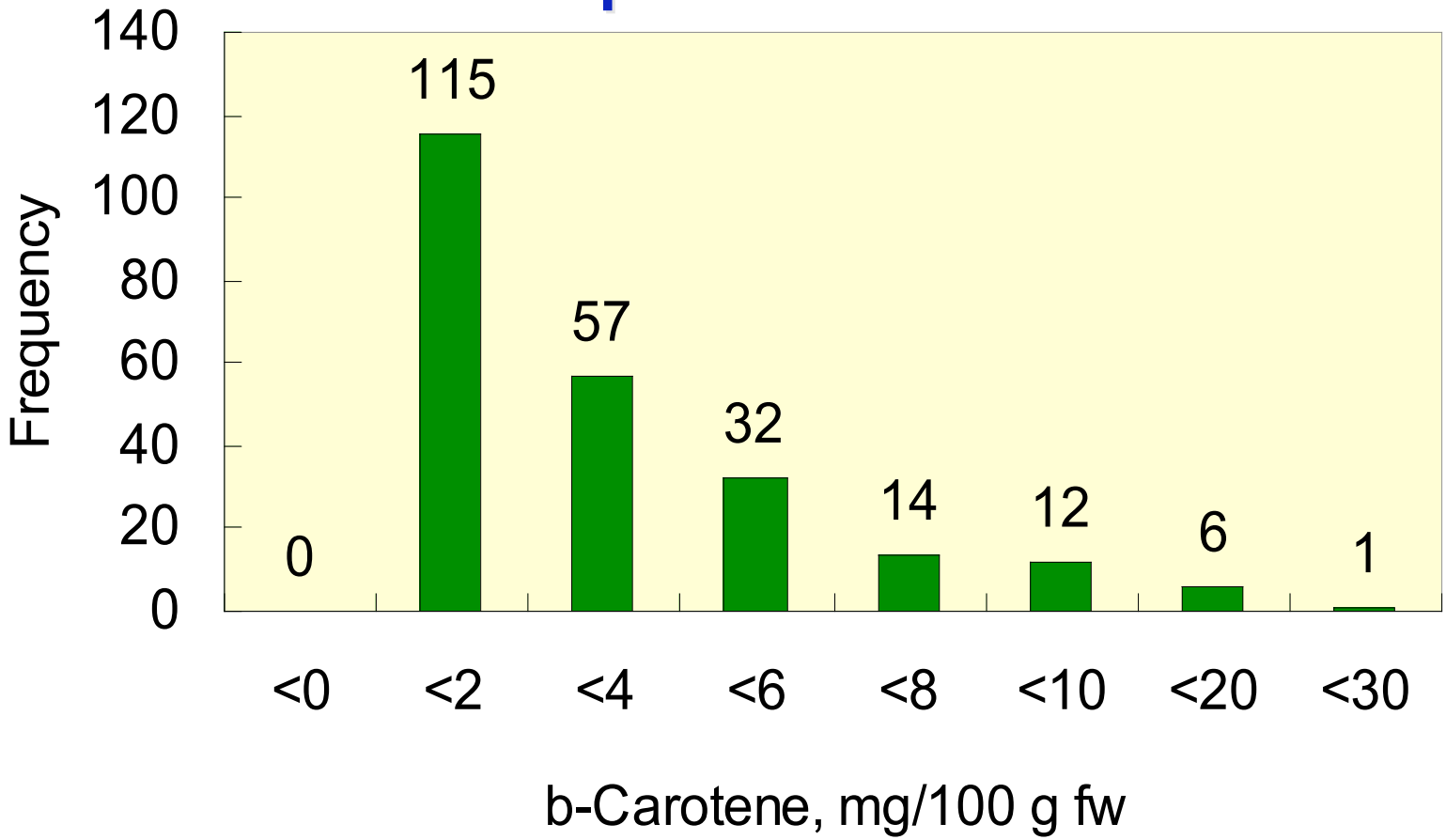


# Nutrient Content Ranges

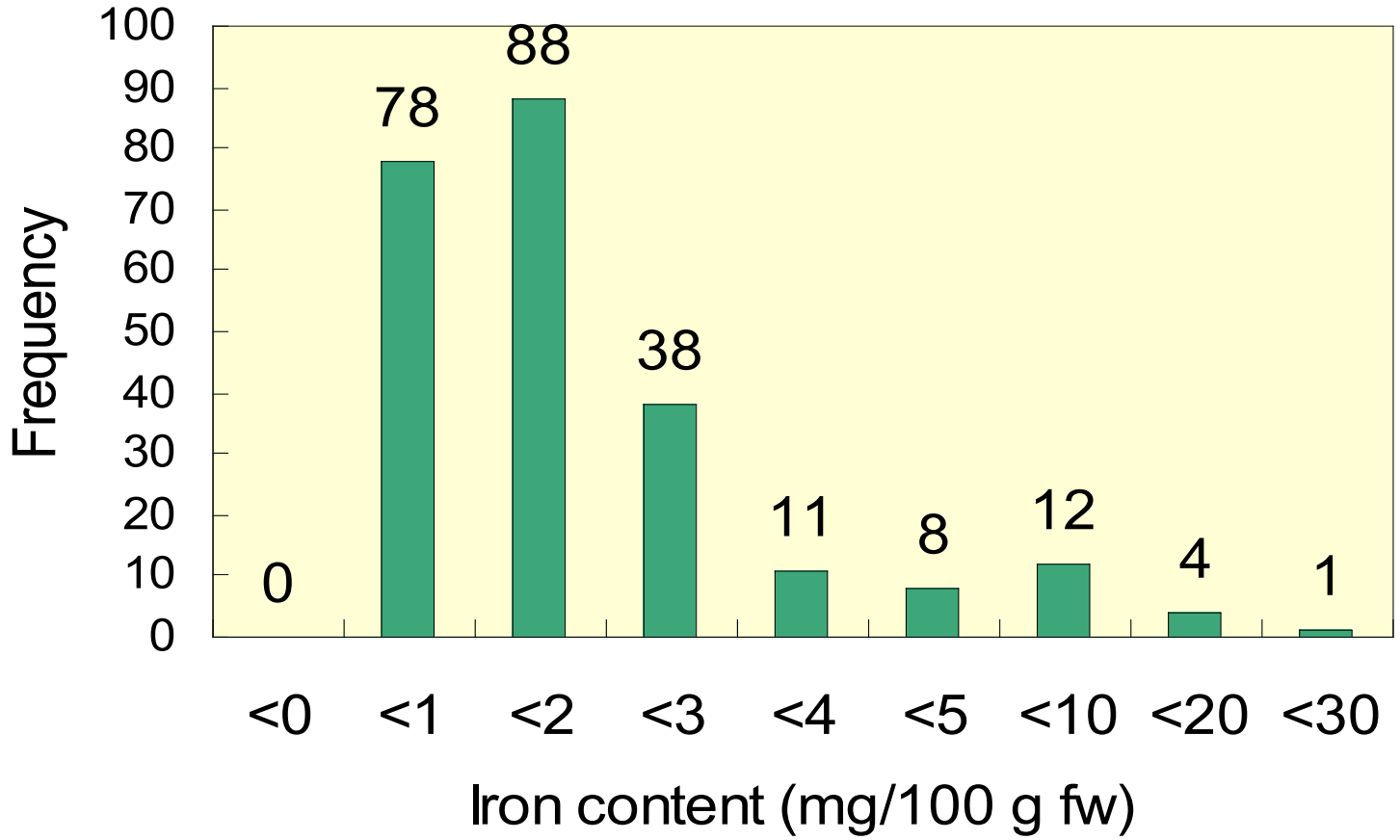
| *In 100 g FW* | *N* | *Min* | *Max* | *Mean* | *SD* |
|---|---|---|---|---|---|
| Protein, g | 243 | 0.2 | 10 | 3 | 1.6 |
| β-carotene, mg | 241 | 0.0 | 22 | 3.1 | 3.3 |
| Vit. C, mg | 243 | 1.1 | 353 | 70 | 77 |
| Vit. E, mg | 243 | 0.0 | 71 | 2.6 | 5.6 |
| Folates, μg | 90 | 2.8 | 175 | 51 | 40 |
| 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 |

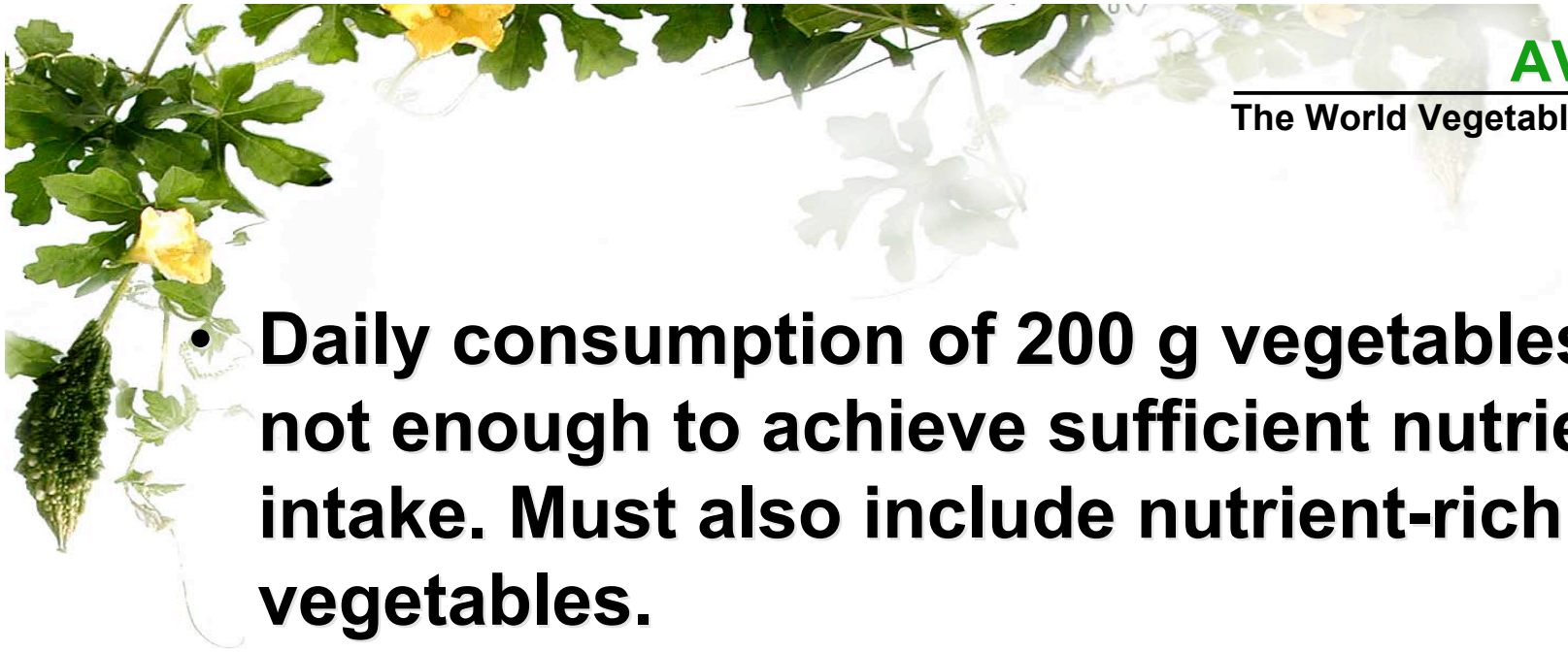
Specie no.: ~120

# 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

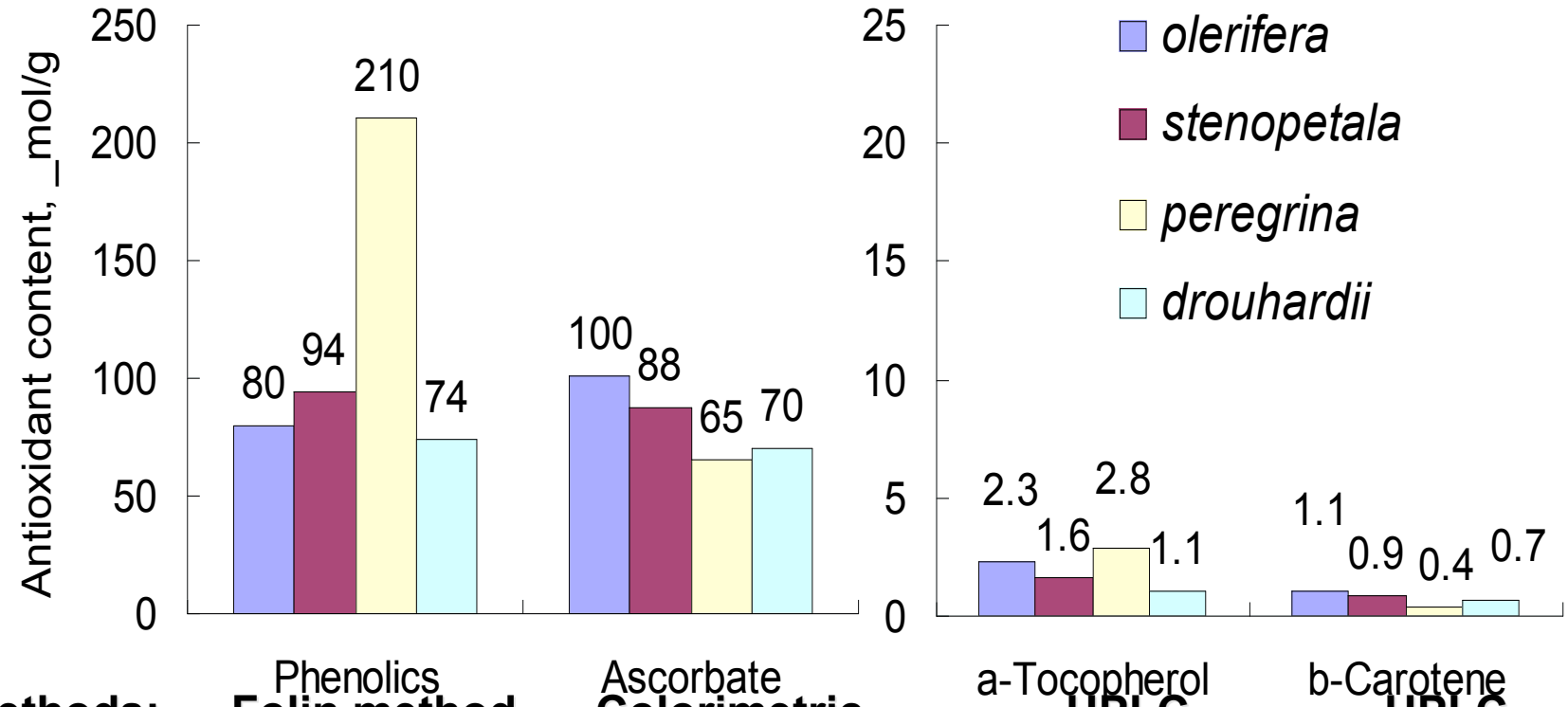
100 g fresh mature leaves

| 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)



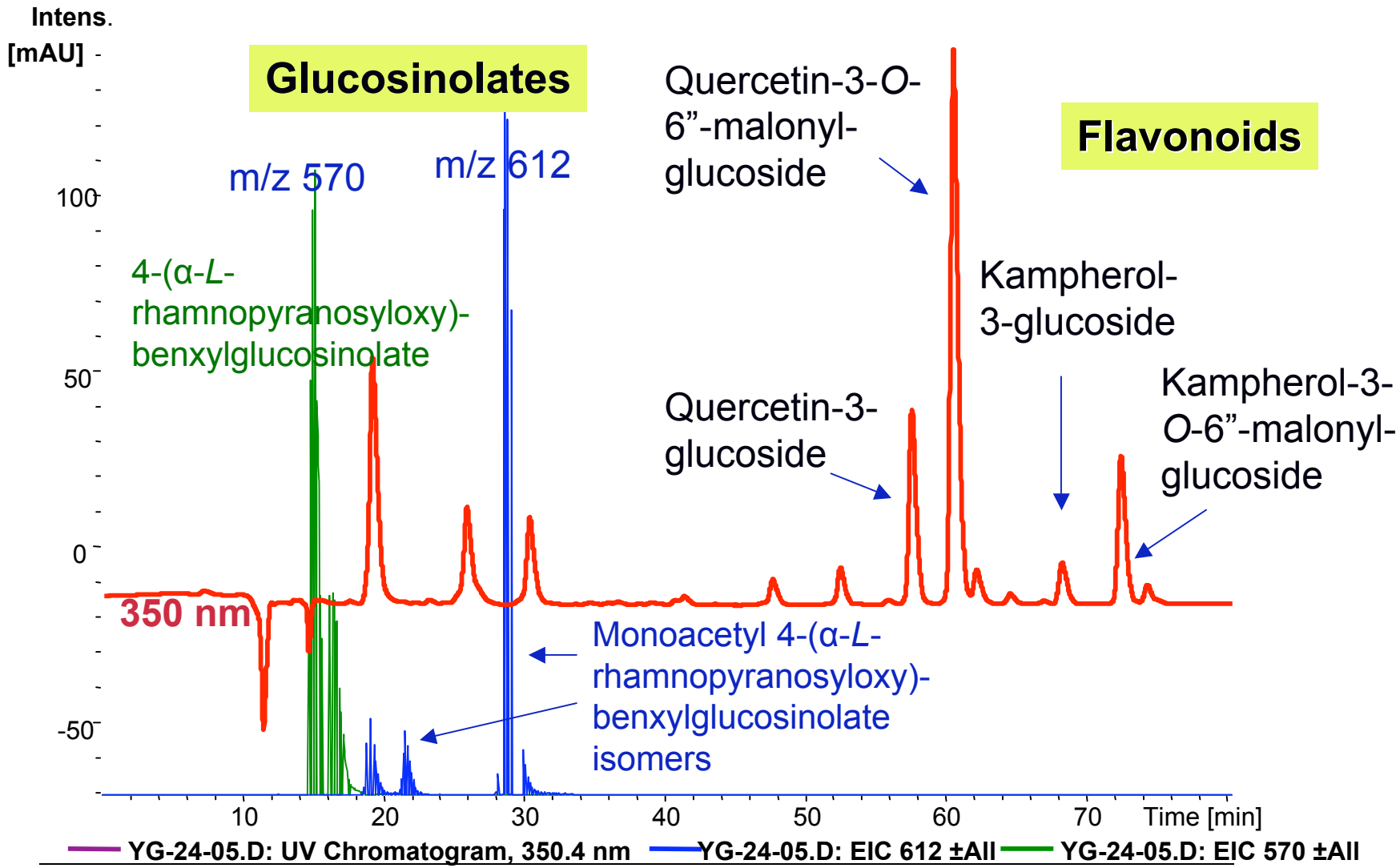

**Methods:** **Folin method,** chlorogenic acid equivalents

**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

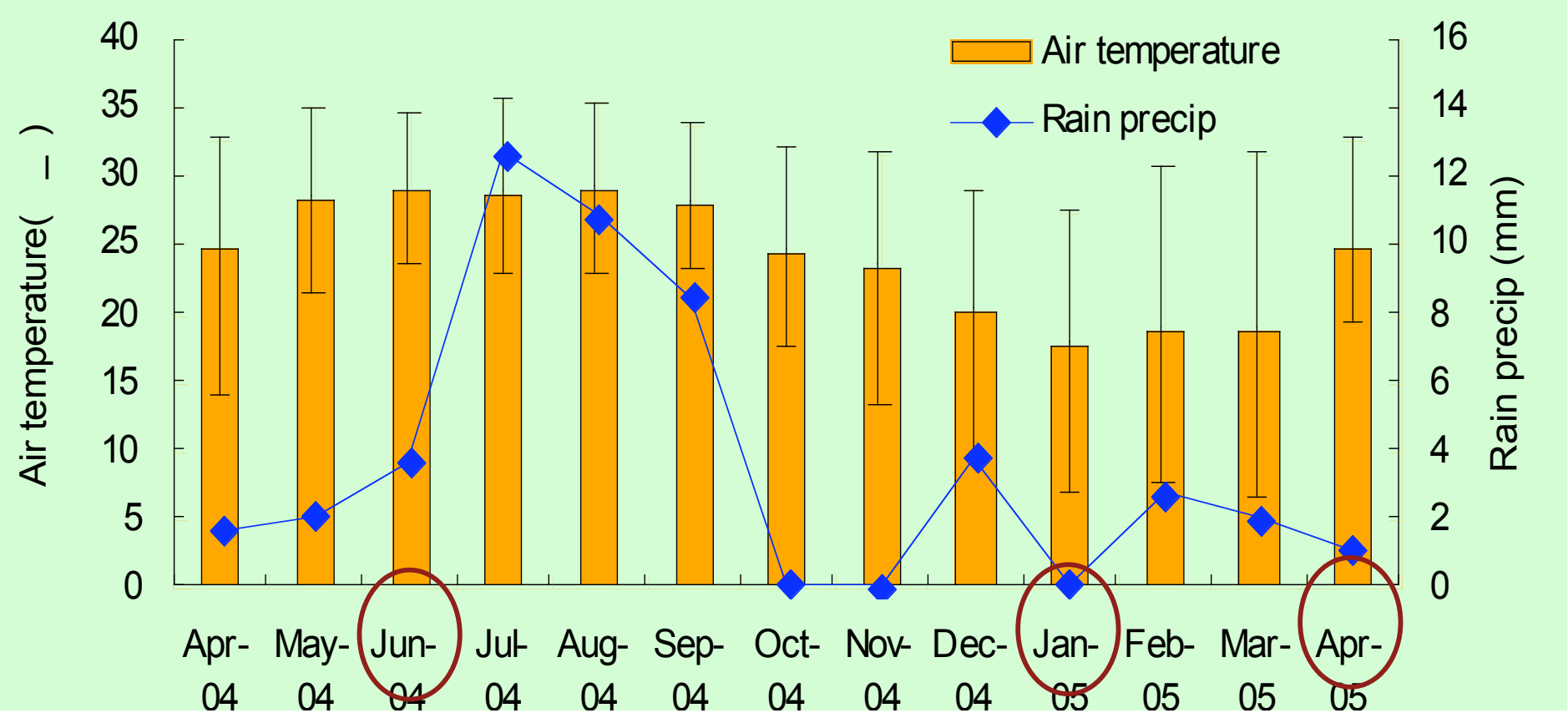
- **Experimental design**
  - **RCBD**
  - **Factors:**
    - **Variety: 10 *M. oleifera* accessions, 3 field replications**
    - **Leaf type: mature, young shoots**
    - **Harvesting season: hot-wet (June), cool-dry (Jan), spring (April)**
- **Analyses:**
  - **Protein, 3 vitamins, 2 minerals, phenolics,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

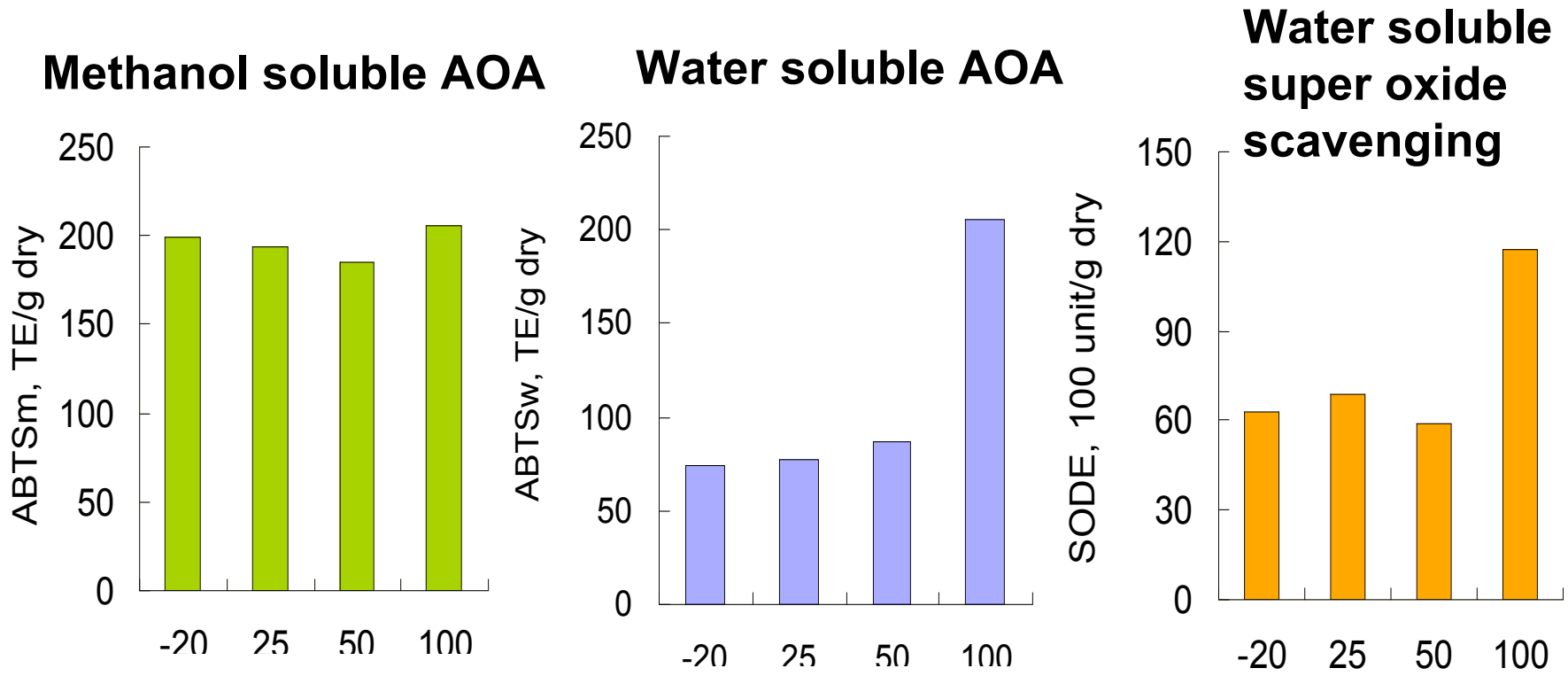
# Mature leaves for commercial products: Leaf extracts and tea bags sold in Taiwan

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

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

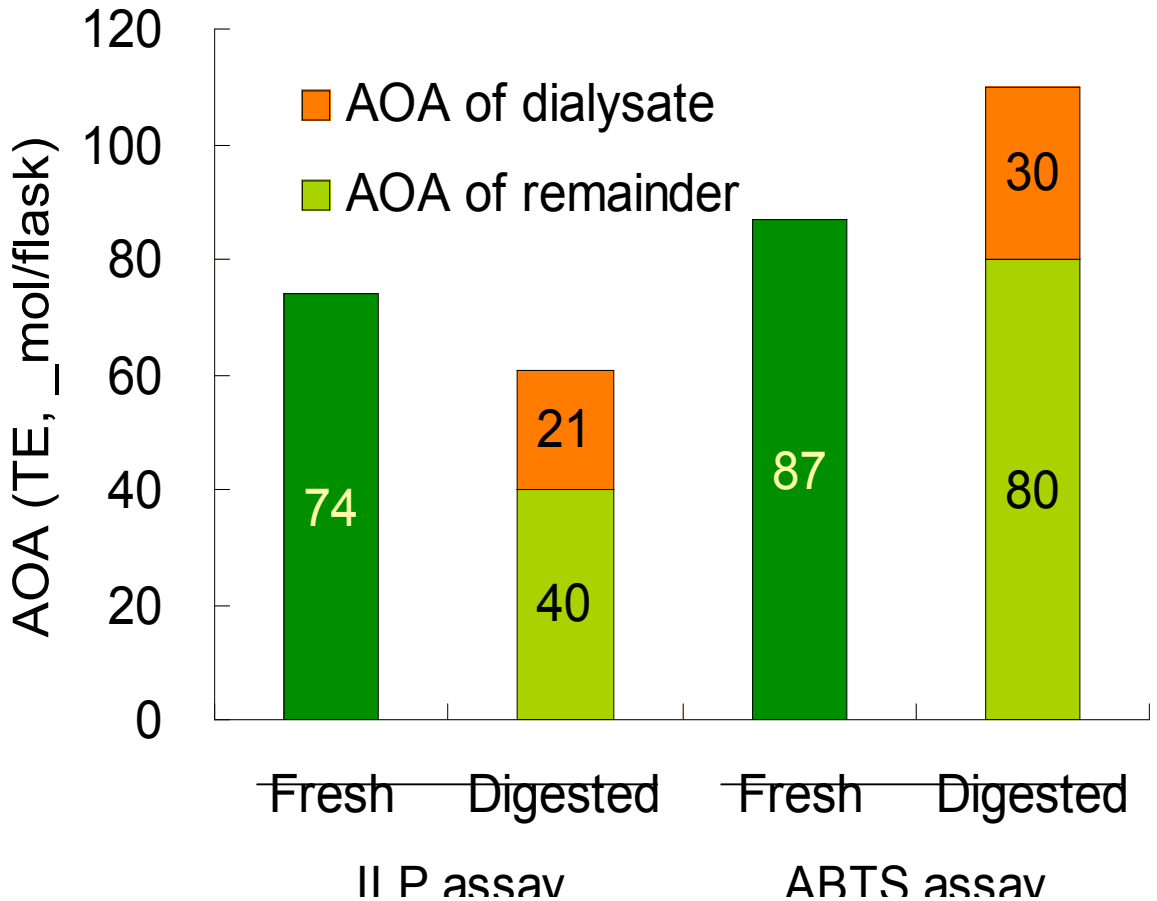
| Per 100 g DW | Freeze dry | 50°C dry |
|---|---|---|
| Protein, g | 28 | 28 |
| Fiber, g | 8 | 8 |
| β-Carotene, mg | 154 | 110 |
| Vitamin C, mg | 582 | 157 |
| Tocopherols, mg | 169 | 165 |
| Calcium, mg | 1760 | 1670 |
| Iron, mg | 20 | 21 |
| Polyphenols, g | 3 | 3 |
| Glucosinolates, mmol | 8.6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

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

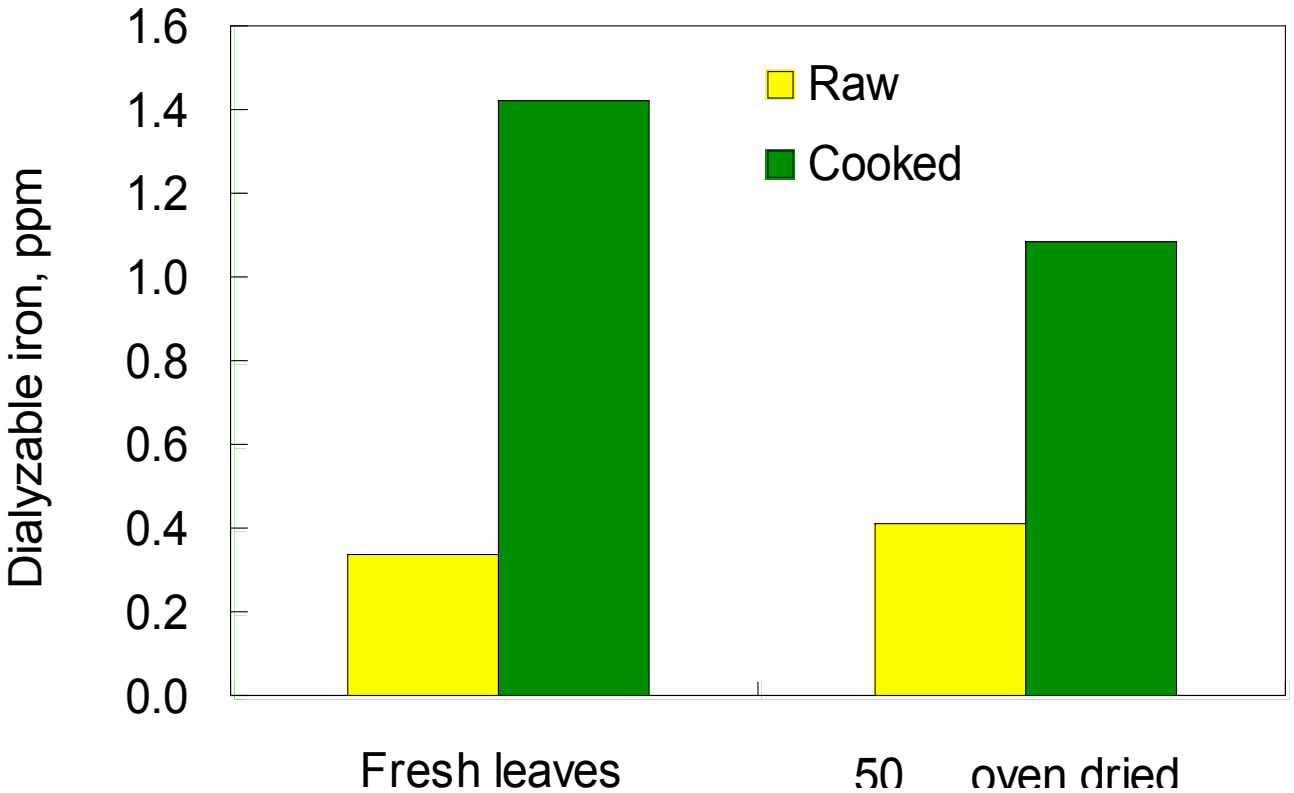



| Treatments | | | |
|---|---|---|---|
| Freezing | Fresh | Mild heat | Boiling |
| -20°C / 4hr | RT, 25°C | 50°C/10 min | 100°C/10 min |

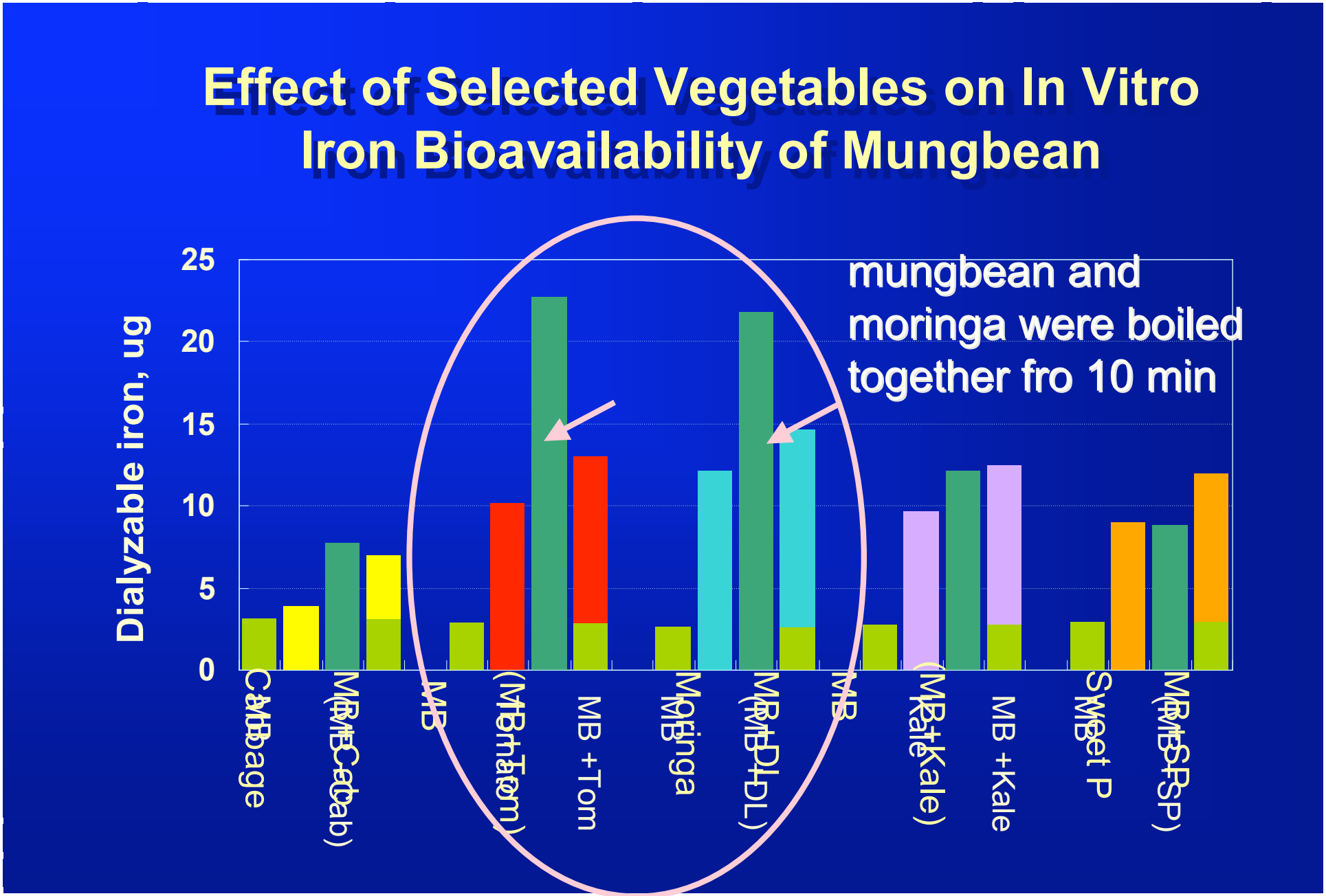
# AOA changes before and after simulated digestion



# 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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| Rutgers, the State University of New Jersey | Food Science Dep. and Adv Food Technology Center | Prof. TC Lee |


Moringa Oleifera Tree