

## METROLOGY INNOVATION MODEL APPLIED TO THE VALUE CHAIN OF GREEN FOOD PRODUCTION

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**Abstract:** This paper describes how innovation in metrology is interlinked with innovation in products and processes and strong implications of this fact for green growth.

The *Taxonomy of the ways of innovation in metrology* [1] and a model based on the study *An Assessment of the United States Measurement System* [2] have been used.

The project consists on the validation of an innovative technology for green and effective growth of crops developed by one of the authors of CBM™ [3]. This is done through three blocks of tests and measurements in equal sets of metrological disciplines.

The study presented is a demonstration of the value that metrology can provide for radical innovation in the field of green production of food.

**Keywords:** metrology innovation; organic food production.

### 1. INTRODUCTION

#### Protected agriculture

Two main concerns of society, governments and NGOs in this globalized economy are the preservation of the environment and the overcome of the actual situation of food shortage in the global scale. In both global aims metrology has very significant value to add.

A field in which this can clearly seen is that of protected agriculture. This is a growing field in the whole world and could help to fulfill several aims:

- Make food production possible and more efficient in areas of the world in which the climate is adverse or too variable.
- Help to optimize natural resources underutilized, as the sun radiation, wind and soil.
- Help to preserve and optimize other scarce resources as water, organic fertilizers, etc.
- Produce more and better foods, at lower prices and in poor areas.

- Provide means for small producers, even in poor environments, to grow their own food.
- Harness research, technological development and innovation towards the aim of eliminating hunger in the world.
- Help to organize interinstitutional and interdisciplinary teams to achieve that aim.

An example of these factors is reported in this paper. It is a joint project among industry, a research center, a university and government. The common aim is to validate an innovative cover and material used for protected agriculture, in the sense that it controls —‘tunes’—, the spectral radiation transmitted to the crops.

#### Control of the radiation spectra

The control of the radiation spectra, within specified limits according to the geographical area, increases the effectiveness of the Photosynthetic Activity Radiation (PAR) and this produces outstanding results in the crops.

The main results observed are:

- Faster growth.
- Stronger plants.
- Longer production cycles.
- More density of plants per area unit.
- Higher nutritional characteristics of the agroproducts.

#### Relevance for Mexico

Mexico is a country with rather high radiation flows, higher than 2,500  $\mu\text{mol}/\text{m}^2/\text{s}$ . Solar stress produces cellular damage in the plant surfaces, decoloration, dehydration and reduction of the agroproduct quality. Studies have shown losses of the commercial value in the order of 8% to 50% due to the solar stress.

#### Bioclimatic Cover (CBM™)

The Company “*Cubiertas Bioclimáticas de México*” has developed studies about the effect of the solar radiation in crops. It has correlated the normal radiation with the Photosynthetic Activity Radiation (PAR).

Based on this studies, the company has developed a new generation of cover (CBM™) with photochemical action that constitutes a shield against UV radiation. During 2007 to 2009 the covers were designed, manufactured and evaluated preliminarily.

The *Cubierta Bioclimática*™ would allow designing and further developing new productive models as hydroponic agriculture at high densities —e.g. 5,000 to 8,000 trees/Ha).

### Relevance for Mexico

This has a great potential for Mexico, due to the mentioned climatic conditions and to the low socio-economic conditions of many areas of the country. Similarly, this breakthrough technological innovation would help other areas to face the world's shortage of food, allowing many regions to be productive and to take advantage of the always limited natural resources.

In Mexico there are not technical standards or technical guides that specify the optimal climatic conditions of production for horticultural products, fruits and ornamental products.

## 2. OBJECTIVE AND METHODOLOGY

### General objective

The objective of this project is to validate the performance of the new product developed, mainly in three areas:

- a) Material composition and performance.
- b) Radiometric filtering and photosynthetic activity.
- c) Nutritional impact on different crops with biometrology and biochemical analysis.

To make a full correlation with the **results** of these three series of studies and produce a model for optimum design of agro-productive areas.

### Models applied

As mentioned in the abstract, the methodology applied for the validation of the CBM™ is following the *Taxonomy of the ways of innovation in metrology* [1] and the model referred in *An Assessment of the United States Measurement System* [2].

In the first reference, the main ways of innovation in metrology have been classified as:

- a) Innovation in scientific metrology
- b) Innovation in industrial metrology
- c) Innovation in industrial processes with metrology.

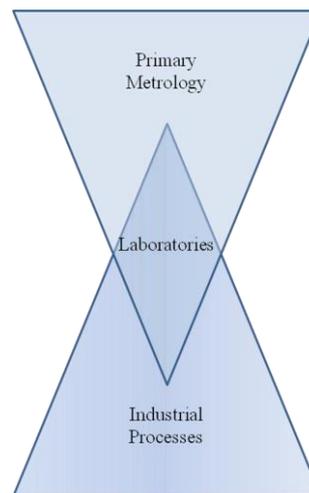


Figure 1. Levels of innovation in and with metrology [1].

The work in this project impacts the three levels mentioned above. a) A new system of solar radiation simulation is being established at CENAM, the primary laboratory of metrology in Mexico. b) Instruments used for measuring radiation flow in the field will be certified for their use. c) The 3 sets of measurements mentioned will contribute, each on its field, to material development and agro-product development.

The incursion of the 3 fields of metrology involved can be seen, also, from the perspective of the NIST Model [2]. From this perspective, there are mainly 3 stages: a) Material, b) Physical performance on the field, c) Biological performance on the agroproducts.

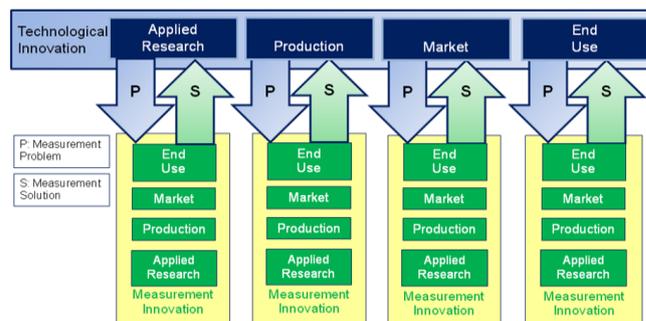


Figure 2. The process of product innovation with support of the metrological innovation [2].

## 3. DEVELOPMENT

The project is developed in two main sites: a) Agro-Industrial at CBM™ and b) Laboratory at CENAM.

Production of the cover is done at the industrial company. Agricultural work is done at the farm of the company, near the coast area of Mexico.

Laboratory work is done at CENAM, in central Mexico. Specific testing modules for agricultural work are established at CENAM, to have overlap and redundancy in testing.

**Table 1. Stages of the project is as follows.**

| Ph | CBC   | CENAM  |
|----|---|--|
| 1  | Common Planning – Design of Experiments                     |  |
| 2  | Acquisitions, training, facilities construction and seeding | Material analysis and integration of measurement systems |
| 3  | Crops, growing and protocol development                     | Validation of radiation measurements                     |
| 4  | Follow up of crops, continuous measurement                  | Follow up of crops, continuous measurement               |
| 5  | Harvesting and analysis of results                          | Testing and analysis to selected agroproducts            |
| 6  | Final evaluation and validation                             |  |

**Table 2. Chronogram and activities in each stage.**

| Deliverable  | Period |    |    |    |    |    |    |    |    |    |    |    |  |
|--|--------|----|----|----|----|----|----|----|----|----|----|----|--|
|  | 01     | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |  |
| Material analysis, composition and characterization  | →      |    |    |    |    |    |    |    |    |    |    |    |  |
| Implementation of testing modules and integration of reference systems.                      |        | →  |    |    |    |    |    |    |    |    |    |    |  |
| Measurement of radiation on the field and performance testing.                               |        |    | →  |    |    |    |    |    |    |    |    |    |  |
| Verification of the radiometric performance of CBC®, UV absorption and agroproducts effects. |        |    |    |    |    | →  |    |    |    |    |    |    |  |
| Complete analysis of correlation and final evaluation of the agroproduction system.          |        |    |    |    |    |    |    |    |    |    | →  |    |  |

**Types of techniques applied in each field.**

- a) Analysis of materials.
  - Espectrometry FT-IR y FRX.
  - Mass Ionization Espectrometry Positive (MS+) and Negative (MS-).
- b) Radiation measurement and analysis
  - UV-Vis-IR Espectrofotometry.
  - UV Radiation measurements with primary detectors. Radiation measurement in the whole UV-Vis-IR spectrum.
- c) Biochemical measurements and nutritional aspects.
  - Different analytical techniques, according to the needs including measurements of:
    - Proximal analysis: Protein, carbohydrates, fat.
    - Other nutrimental substances: Minerals, vitamins.
    - Nutraceutical substances: antioxidants, flavonoids, etc.

**4. PROCESS AND RESULTS OF STAGES 1-2**

**Material analysis**

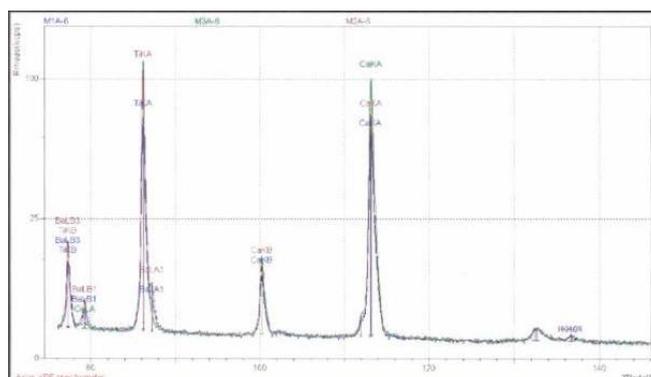
The analysis of the material was done using 3 types of analytical techniques:

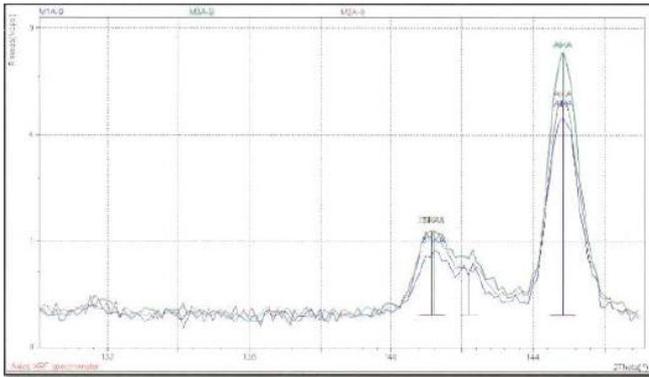
- a) Qualitative analysis: Fourier Transform Infra Red Spectroscopy (FT-IR).
- b) Semi-quantitative analysis: X Ray Fluorescence Spectrometry (FRX).
- c) Elemental chemical micro-analysis: Energy Dispersion X Ray Spectroscopy (EDEX) with Electro Scanning Microscopy (ESM).

Three types of CBM™ have been analyzed:

- Sample 1: 350 µmoles/s/m<sup>2</sup>
- Sample 1: 500 µmoles/s/m<sup>2</sup>
- Sample 1: 700 µmoles/s/m<sup>2</sup>

Figures 3a and b show examples of the FRX Semi-quantitative analysis made to the 3 samples. It shows the main presence of Titanium and Calcium, with other elements in lower concentrations.





**Figure 3. Examples of the results obtained with the FRX Semi-quantitative analysis .**

The composition results are given in the following table.

**Table 3. Sample composition.**

| Composition                                  | Sample 1<br>350 moles/s/m <sup>2</sup>                                       | Sample 2<br>500 moles/s/m <sup>2</sup>                                       | Sample 3<br>700 moles/s/m <sup>2</sup>                                       |
|--|--|--|--|
| <b>Qualitative analysis of base material</b> | Polipropilene (89% correlation)<br>Polietilene low density (41% correlation) | Polipropilene (89% correlation)<br>Polietilene low density (63% correlation) | Polipropilene (95% correlation)<br>Polietilene low density (63% correlation) |
| <b>Semi-quantitative elemental analysis</b>  | Titanium (40%)<br>Calcium (20%)<br>Zinc (2%)                                 | Titanium (37%)<br>Calcium (20%)<br>Zinc (2%)                                 | Titanium (46%)<br>Calcium (24%)  |
| <b>Elemental chemical micro-analysis</b>     | Titanium (50%)<br>Calcium (24%)<br>Copper (17%)<br>Zinc (6%)                 | Titanium (66%)<br>Zinc (15%)<br>Copper (11%)<br>Calcium (3%)                 | Titanium (39%)<br>Copper (23%)<br>Calcium (15%)<br>Silica (8%)               |

It is expected that these compositions, together with the different geometrical characteristics of the CBM™ (thickness of the mesh, plastification covers, etc.) will account for the different optical properties expected from each material. This will be tested in the following stage.

Some aspects of the desired behaviour are given in table 4.

**Table 4. Desired behaviour of the cover along the radiation spectrum**

| Radiation            | IR<br>< 400 nm   | VIS<br>400 – 800 nm   | UV<br>> 800 nm   |
|----------------------|--|---|--|
| <b>Reflectance</b>   | Reflectance should be increased in heavy radiation areas to avoid overheating of the green house | Reflectance should be avoided, since this radiation (PAR) increases photosynthetic activity | Reflectance should be increased since UV radiation stresses plants and damages the cover |
| <b>Absorbance</b>    | Absorbance should be kept low to avoid overheating of the cover                                  | Absorbance should be kept low to allow maximum PAR transmission                             | Absorbance should be kept low to avoid depolymerization of the cover                     |
| <b>Transmittance</b> | Transmittance should be modulated to control temperature   | Transmittance should be optimum to allow all the PAR radiation to reach the plants          | Transmittance should be minimum to protect the plants from stressing radiation           |

## 5. EXPECTED RESULTS

Each set of measurements will lead to specific results to validate each of the products: material, cover and agro-products.

The whole agro-production system will be validated through a complete statistical analysis of metrological data in each of the stages.

Techniques as DOE, ANOVA, etc. will be applied all through the process. Metrological qualities of the measurements as reference to primary standards, traceability, method validation, etc. are cared in every data obtained.

For the date of the Congress, data of the main stages will be already available

## 6. REFERENCES

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