Research project **Biocolor**: natural dyes from plant materials and agricultural by-products

Introduction

Color is an important criterion of attractiveness and acceptability of many products, such as textiles, cosmetics and food. While dyes were exclusively natural in the past, this changed in the 1850s when mauveine was the first synthetic dye to be produced. Due to high expectations concerning the performance of colorants, the majority of dye substances used in several industries nowadays have a synthetic origin. A disadvantage of the synthetic dyes is its potential to cause health problems and its harmful effects on the environment. Therefor, regulations for the use of colorants has become more strict during the last decades. Coupled with the ecological awareness of consumers, the development of high-performing natural dyes is in high demand.

In this context the Biocolor research project (2020-2022) was launched. In collaboration with its industrial and academic partners, the project examined the potential of plant materials and agricultural by-products as a source for high-performing colorants. Textiles, food and candles were chosen as case studies to apply the produced dyes. The agricultural residues and biomass that will be used for this project are principally available in Belgium and the Netherlands.

Candles

This case study describes the use of natural colorants to produce colored candles made of soy wax. Unlike the case studies of textile and food where colorants were water soluble, a lipid soluble colorant is necessary to blend with the soy wax.

This report will present the following:

- Drying of plant materials
- Extract addition to soy wax
- Infusion of soy wax

Drying of plant materials

Depending on the plant material, a drying step is necessary to prevent deterioration of the biomass during its storage. Wet materials like green leaves, flowers and roots can quickly become moldy when not taken care for properly. Some agricultural by-products however are dry by themselves. A good example of this case are onion peels, which are separated from the bulb during the sorting process once harvested.

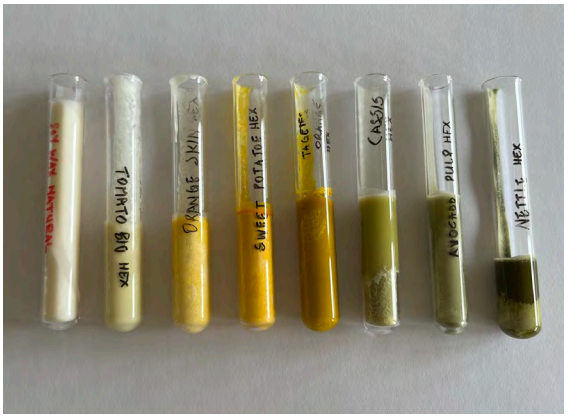
During this project, freeze drying was used to dry all materials to be able to compare the coloring capacity of each material on a dry weight basis.

Once dried, the plant material is milled to reduce particle size and increase the contact surface for extraction purposes.

Extract addition to soy wax

The solvent hexane was used to extract the coloring substances from the plant materials and agricultural by-products. Hexane was chosen since it can extract lipid soluble components from the dried materials. To do so, the Accelerated Solvent Extraction (ASE) machine from Thermo Fisher Scientific was used. This machine automates the extraction protocol at elevated temperature and pressure, thereby ensuring a more efficient extraction compared to traditional techniques like Soxhlet.

The produced extracts were added to melted soy wax, after which the hexane was removed using the rotary evaporator. In this way, the colorants were easily transferred to the soy wax and distributed evenly. Some plant materials were able to deliver bright colors to the soy wax. However, the color range achieved by the natural colorants was rather limited.



The picture shows from left to right:

- Natural soy wax
- Tomato
- Orange peel
- Sweet potato
- Marigold flowers
- Blackcurrant press cake
- Avocado pulp
- Nettle

Infusion of soy wax

To avoid solvent extraction, infusion of the soy wax was investigated as an alternative method. Plant materials were placed in tea filters and left to soak in melted soy wax at 60 °C. An infusion time of 24 hours gave some vibrant colors to the soy wax. The color range achieved was similar compared to the hexane extracts.

Picture shows from left to right 24 hours infusions of:

- Natural soy wax
- Orange peel
- Lime peel
- Curcuma powder
- Paprika powder
- Madder root
- Nettle
- Avocado seed
- Beetroot

Evaluation of the case study

The use of plant materials and agricultural by-products for the production of colored candles shows promising results. Some bright and pale colors were achieved using natural materials as a source for coloring agents. Yellow, orange and green colors were easily made. However, it was not possible to produce pink, purple or red colors, despite using a range of plant materials with these colours. This is most likely caused by the chemical nature of the anthocyanins, the most abundant naturally occurring group of red colorants.

A big downside to the produced candles was the bad performance in terms of UV stability. When left exposed to indirect daylight, most colors diminished after one month. This is shown in the pictures below.

Left picture shows samples of colored soy wax before UV exposure. Right picture shows the effect of 1 month UV exposure. The left plate contains 'infused' samples of soy wax, while the right plate holds 'hexane extract' samples.

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Attention should be paid to the fact that all results presented in this report were obtained by performing experiments in a laboratory setting on a non-industrial scale.

Some restrictions concerning the use of plant materials were identified during the project:

- To obtain sufficient quantities of raw materials
- To obtain regular supply of raw materials, since some are only available during a limited time of the year
- To obtain stable color results, which do not fade due to UV-light exposure
- To obtain consistent color results, despite differences in the source of the same material

These limitations should be addressed before plant materials can be seen as a perfect alternative to replace currently used synthetic colorants for candles.

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