

A THERMOVISION ASSESSMENT METHOD OF QUALITY FOR OILY SEEDS (*Cannabis Sativa L.*)

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Abstract: *Conditioning the harvested seeds is of great importance for plants with uneven seed development since all the stages of seed maturity are found on the harvested bulk mass. The seeds' classification raises difficulties since the color or shape parameter is not always a clear criterion for discrimination. A fast method of evaluation by using machine vision is desired to provide estimation of the seeds' quality that could be easily implemented and replicated for different plant varieties. The thermal characteristics of ripe seeds as compared to unripe seeds are used as selection criteria against a thermal background that can enhance the contrast between the two categories.*

Key words: *grading of seed quality, thermal imaging, temperature background, color histogram.*

1. Introduction

Fiber plants such as hemp and flax are considered valuable crops for being a versatile source of bio raw materials with diverse applications in agriculture and industry. Industrial hemp plants are regarded as an excellent source of oil rich seeds, fibers and woody shives. Hemp seeds are valuable food supplements for human nutrition and animal husbandry [1]. Originating from central Asia this crop has been cultivated for over 5000 years all over the world.

Hemp seeds are harvested in Europe, as a by-product of natural fiber hemp cultivation. The demand for high quality hemp seeds is estimated to be of approx.

12,000 t for Europe only [3]. Since cultivation and production is insufficient in Europe the demand is covered with high quantities of seeds from import, mainly from Asian and North American countries [3].

The human nutritional advantages of hemp seeds are given by the fact that the seeds contain all eight essential amino acids and are seen as a complementary source of protein in human nutrition [3]. Hemp seeds contain omega-6 fatty acids and omega-3 fatty acids in a nutritionally optimal ratio [8].

Harvested seeds need to be kept at refrigeration temperatures until primary conditioning is ensured, in order to prevent biological activity of the seeds and

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deterioration of oil components. Refrigeration of the seeds immediately after harvest provides high quality nutritional and taste properties of the hemp seeds. Processing and handling can be conducted at room temperature after primary conditioning. The conditioning of the harvesting seeds is of great importance since during the optimum harvesting time all stages of development of the seeds are found on the plant. The presence of immature seeds strongly affects the taste and commercial aspect of the final products since they decay fast and contain high levels of humidity.

Seed classification raises difficulties since the color or shape parameter is not always a clear criterion for discrimination. Unripe seeds need to be excluded from the manufacturing process since they are a source of bad taste and change in color.

Discrimination of ripe seeds from unripe seeds is an essential parameter for both cultivation and economic value of the seeds. The price of the seeds varies greatly according to the size and content dry matter of the seeds. The price range in Europe for purchasing for industrial use is between 0,30 € kg⁻¹ for low quality and 1,00 € kg⁻¹ for high quality seeds that are suitable for human consumption [1].

The nutritional value of the seeds is quite difficult to achieve since it requires determination of lipid and protein content with methods that are time consuming and invasive [6]. A fast method of evaluation [10] and non-invasive [4] is desired in industry to provide a method of estimation of the ripeness of the seeds and a discrimination method that could be easily implemented and replicated for various plant seeds.

2. Materials and method used in the research of seed quality

The experiments conducted were focused

on the non-invasive evaluation of hemp seeds' quality by using the thermal characteristics of ripe seeds versus unripe seeds. The thermal characteristics [7] of ripe seeds compared to those of unripe seeds were used as selection criteria against a thermal background.

2.1. Samples

The studied samples were collected during the harvesting period of the hemp seeds from dew field retting swaths in the fall of 2014. The fiber hemp crops were grown in the experimental fields situated in the vicinity of the Leibniz Institute for Agricultural Engineering Potsdam-Bornim, Germany (52°26'14''N, 13°0'58''E). Two plots of 0.31 ha each, were used for growing two French hemp varieties: Santhica-27 and Fedora-17. Based on the technical data, provided by the seed producer, these hemp varieties have different behaviors [10] in ripening and especially growing height [5].

2.2. Sample collection and storage

The samples used in the experiments were taken from the seeds collected from the two hemp varieties during the time interval of growth of 127 to 154 days after sowing. The variety Santhica had its maximum yield at 139 days after sowing, while the variety Fedora had its maximum yield 6 days later at 145 days.

For the image investigation the seeds were selected from the samples collected during the field swath retting process of the plants. The seeds for the thermal analysis were sorted manually and divided into two groups of ripe seeds and unripe seeds. The seeds were stored in the refrigeration chamber at 3°C.

2.3. Principle of thermal background and seed sample preparation

The thermal background consisted of an insulation material made of polystyrene foam plate that had a higher temperature difference than the analyzed samples. The temperature difference was of about 13 to 17 °C. The background had a high temperature difference from the samples in order to enable a high contrast of the thermal image that was captured with the thermal camera. The result was a good contrast between the seeds and the background as it is presented in Fig.1.

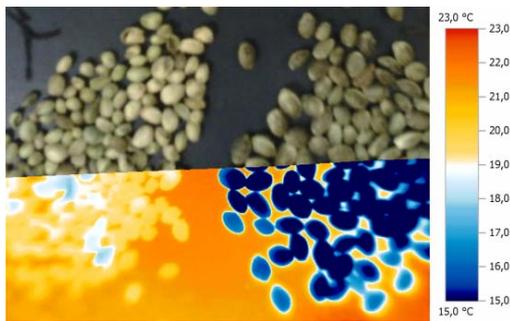


Fig.1. Illustration of the seed samples exposed against the thermal background used for determination of the quality of fiber hemp seeds using the thermo-camera.

In order to avoid heat transfer to the samples by hand manipulation, the seeds were placed on the thermal background by using a metal spatula that had the same temperature as the seeds.

Both unripe and ripe seeds were placed on the background plate to ensure the even temperature of the seeds. Twelve images

were taken for the same sample in a time interval of 1 minute, every 5 seconds. This time interval allowed the seeds to raise their temperature and thus provide a heat transfer behavior that would allow the thermal imaging camera to distinguish the ripe seeds from the unripe.

2.4. Thermal camera image acquisition

To capture the thermal images, a TESTO thermal imaging camera model 876 was used to detect the temperature changes in time of ripe seeds and unripe seeds. The discrimination process took place at a temperature higher than that of the refrigerated seeds, respectively at 23°C.

The TESTO 876 thermal imaging camera model used a detector of 160 x 120 pixels with 19,200 temperature measurement points offering good image quality. Thermal sensitivity was less than 0.08°C which was a temperature resolution that allowed small temperature differences to be visible. The TESTO 876 thermal imaging camera is equipped with integrated digital camera in order to make parallels to the thermal image, a real image of each measurement sample. The camera allowed focalization of the image by using the motorized focus function.

2.5. Software and data analysis

The image analysis of the digital infrared images was processed using the Testo IIRSoft ver. 3.1 SP3 as presented in Fig.2.

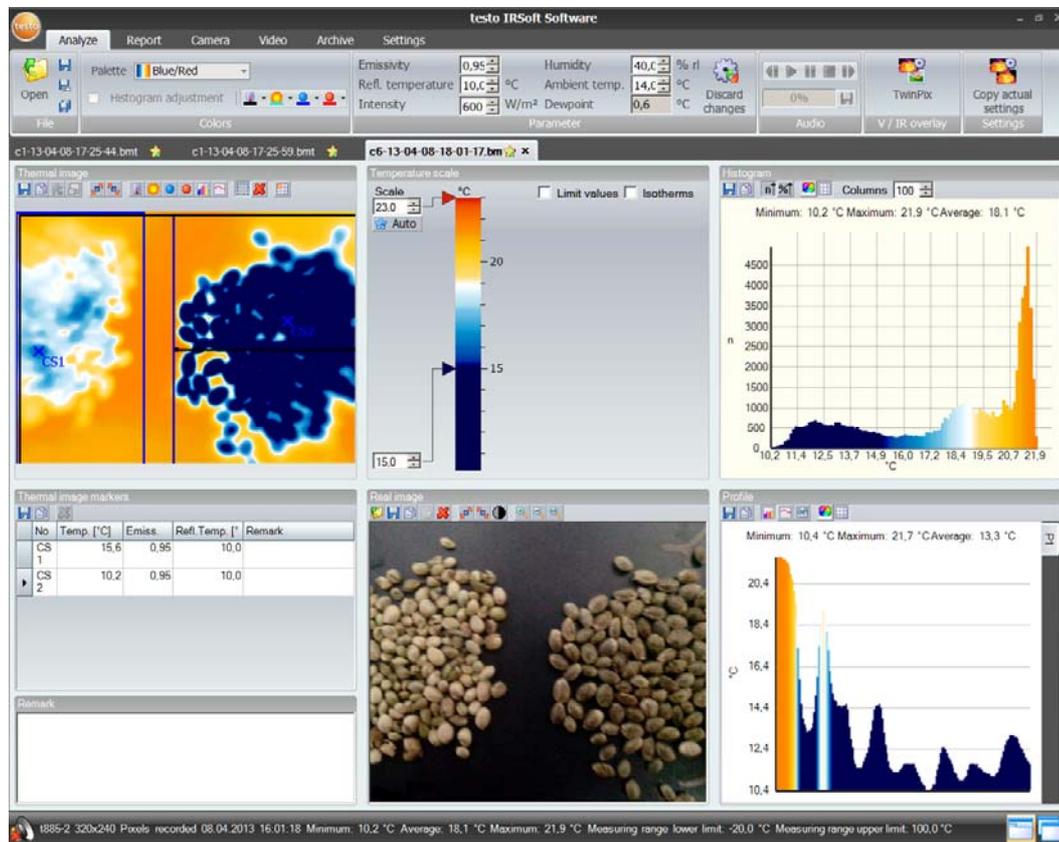


Fig.2. Graphic user interface of the software used to process the thermal images of the fiber hemp seeds.

The software provided both the infrared image and the real image of the sample.

A histogram could be generated for a selected area of the infrared image made by the operator using the software selection tools.

The temperature profile was also given for the established measuring line defined by the operator using the thermo camera software on the infrared image.

By overlapping of the real image and the infrared image with the software option was possible in order to identify exactly the discrimination selection and check the results of the identification, as seen in Fig. 1.

The two categories of the ripe and unripe seeds were then grouped separately and exposed to the thermal background.

3. Results and conclusions

The method revealed a very good contrast between seeds that were mature and with a starchy pulp versus seeds that were unripe and consisted mainly of an empty shell or partially filled shell. The assumption that the ripe seeds would change their temperature slower, versus seeds that were immature and would more rapidly reach a higher temperature was validated by the experiments. Thus, the method of ripeness determination by temperature characteristic of ripe seeds vs. unripe seeds offered a quick discrimination method and a very simple estimation tool of the sample quality.

The change in the temperature of ripe seeds versus unripe seeds is presented in

Figure 3. The mean temperature difference between the two seed classes was of 3 °C.

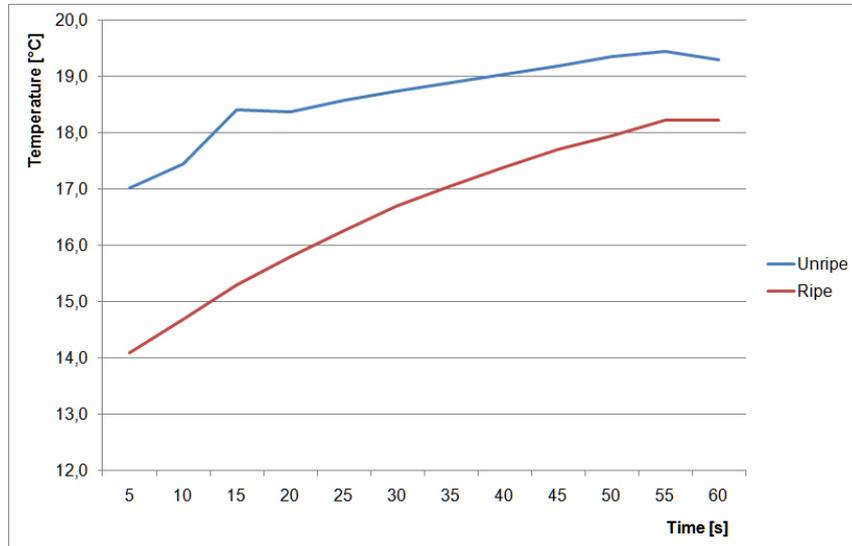


Fig.3. Thermal behavior of ripe seeds versus unripe seeds.

This thermal behavior of seeds is given by the fact that ripe seeds contain more dry matter and are capable of storing more energy while unripe seeds are mostly an empty shell that has less storing capacity.

The phenomenon is best seen in the thermal images taken of the samples exposed to a higher temperature for 1 minute, every 5 seconds.

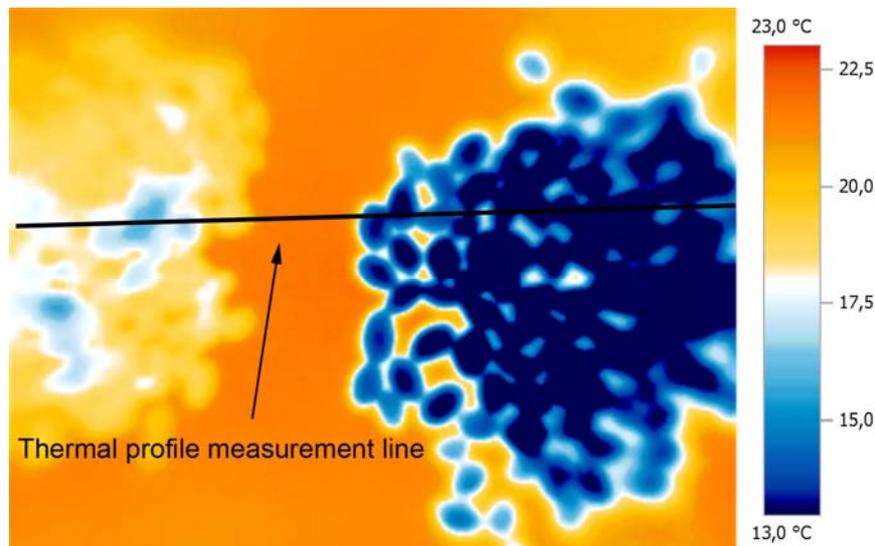


Fig.4. Measuring line for the points of the temperature profiles.

To properly present the thermal variation on the thermal image, a measuring line was

established by the operator so that it would cover a wide variation of pixel intensity in the picture. This reference line was used for all the thermal images in order to compare the same measurements in time.

The line was established to cover the most representative thermal points in the image. In Figure 4 the tool used to provide the measuring line used in drawing the comparison is presented.

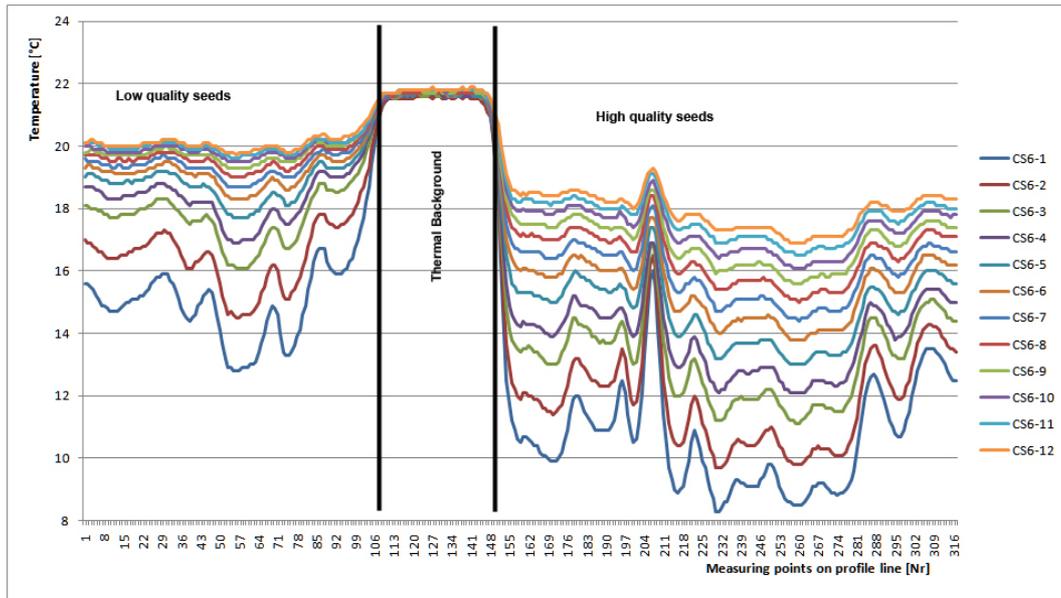


Fig.5. *Temperature profiles of the thermal images taken of ripe seeds (right) and unripe seeds (left) given along a measuring line.*

By analyzing the temperature profile of the images in Fig.5 it can be concluded that the contrast between the unripe seeds and the ripe seeds was very solid due to the thermal background and the specific thermal behavior of the seeds. This situation represents a favorable factor in the quality estimation of specialized software [2] that require a significant difference between pixel color intensity. By using specialized tools that apply statistical determination of the pixel color

intensity, based on the temperature interval and the exposure time, a fast and quick quality analysis of the seeds during transport inside the production process can be performed [11]. The contrast of the seeds in the picture is enhanced by achieving a strong thermal background at a higher temperature that allows pixel evaluation methods to provide a good discrimination between pixel color intensity as it can be seen in Figure 6.

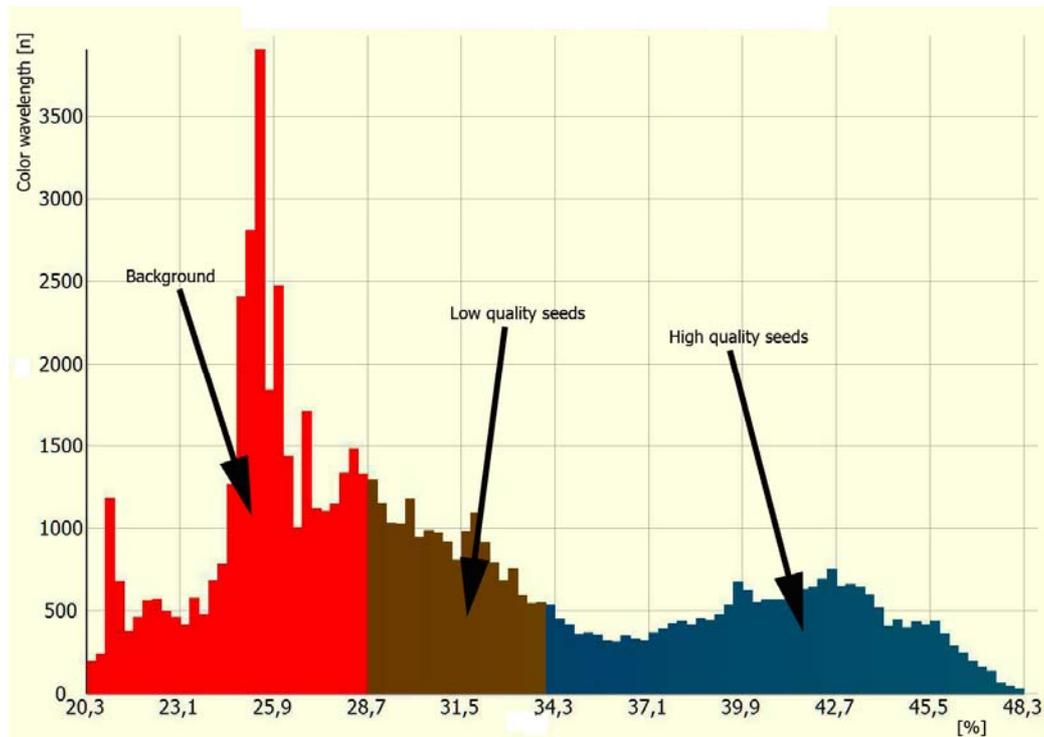


Fig. 6. Pixel histogram of the two seed categories.

The pixel image analysis provided surprisingly good results and it is the basis for developing a method of rapid quality estimation with good replicability for seed samples of different plant varieties. This is a good alternative to systems based on discrimination parameters that use color and shape.

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