Development of Image Analysis Methods to Evaluate Barley / Malt Grain Size

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Abstract

It is known that the barley / malt grain size is an important factor regarding the uniformity of malting process and hence the brewery process. For that purpose an image processing and analysis system was built for the evaluation of grain / malt size, on the *ImageJ* public domain platform. A programme was developed for the barley / malt images treatment and determination of several morphological parameters as well as the grain size distribution. The results showed that for the *Prestige* and *Scarlett* barley varieties good correlations could be obtained between the standard weight distribution and the proposed image analysis method. For the *Esterel* malt and barley as well as for the *Nevada* barley reasonable to good correlations were also obtained upon the introduction of a density correction factor.

1 Introduction

In the process of grain selection for the malt producers or the brewer industries, grain size evaluation is regarded as a fundamental step. In fact, on the occasion of the barley purchase its bore is a parameter of valuation / approval of the raw material, since the grain size has influence on market value and guarantees uniformity of malting process. With the purpose of a rapid grain evaluation in order to agile the barley crop purchasing process, an image analysis technique is proposed. This *in situ* technique for grain size evaluation should then allow for a fast and simple enough field work process of barley / malt assessment and selection.

Image analysis is, nowadays, a well-established complement of optical microscopy. The term image analysis, commonly used embraces not only the analysis of image properly said, as also the previous processes of capture and treatment of the image, that are of primordial importance (Dougherty, 1994). The image analysis makes possible the enhancing of images, as well as the identification and automatic isolation of particles for their study, being one expedite technique that allows the attainment of morphologic information, providing concurrently a reduction of time and work (Russ, 1995).

The main objective of this work was, therefore, the development of an image processing and analysis field methodology allowing determining the barley / malt grains weight distribution throughout commonly used size ranges within the Supply Chain Management from the barley crop purchasing to the quality reception control. For that purpose it was studied the best configuration of a sampling black Bristol box as well as the development of the afore-mentioned image analysis programmes in a public domain open source platform.

Regarding the barley / malt grains weight percentage assessment the proposing method relied on the volume determination of each barley / malt grain, multiplication by a density function factor and ulterior weight distribution estimation for the studied size ranges. In order to evaluate the performance

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of the current image analysis (IA) proposed method the obtained results were thereafter plotted against the traditional standard EBC method (Analytica EBC, 1998).

Keeping in mind that such a methodology was developed for a field analysis, it was also found to be of the utmost importance the establishment of a precise acquisition procedure and the evaluation of its robustness and sampling size. Regarding the method robustness emphasis was taken on camera resolution, with the determination of the acceptable minimum resolution, whereas for the sampling issue the minimum barley / malt sample number was established.

2 Materials and methods

The current work was developed in three distinct stages: The first one is related to the sampling and grain size determination by the standard EBC method, the second to the development of the image analysis (IA) proposed methodology and the third to the proposed IA method results evaluation.

In the first stage the afore-mentioned barley / malt varieties were sampled and characterized by *Unicer* technicians accordingly to sampling assays respecting the *3.11.1 Analytica EBC "Sieving Test for Barley"* method. Assays were performed with 5 different lots of barley / malt varieties: *Scarlett*, *Nevada*, *Esterel* and *Prestige* barleys and *Esterel* malt.

The second stage consisted on the development of the image processing and analysis programmes, determination of the grains morphological parameters, weight percentages estimation and performance evaluation regarding to the standard method. Sub-samples of the grains used in the first stage were employed so that a comparable set of results could be obtained. Three steps compose this stage consisting on grain image acquisition, image treatment and analysis and finally parameters determination. In the development of these procedures emphasis was taken on designing a low cost solution and therefore a *Hewlett Packard* digital camera was used (2.24 megapixel), alongside the public domain open source *ImageJ* (*NIH*, USA) platform. In each image acquisition about 36 grains were placed in the specially built black Bristol board, containing a 1cm ceramics gauge block (*Mitutoyo*) for grain size calibration. An average acquisition of 16 images per barley / malt variety was carried out for both front and side views resulting in the characterization of around 550 individual barley / malt grains. The acquisition methodology is represented in Figure 1 and example front and side views images are presented in Figure 2.

Figure 1 – Front (a) and side (b) views acquisition methodology.

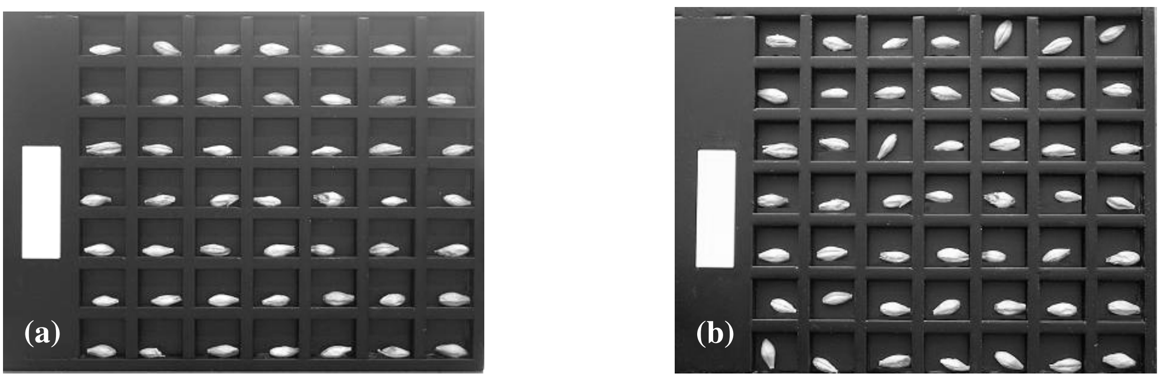

Figure 2 – Images form the front (a) and side (b) views from the grains.

Concerning the image processing and analysis programme, a macro of commands in *ImageJ* native language was developed consisting in five major sections: Image pre-processing; identification and measurement of the ceramics gauge block; image segmentation with barley / malt grains identification; debris elimination and finally the grains morphological parameters determination. Both front and side view images were treated in order to obtain a detailed description of the overall morphology and for each individual grain the morphological parameters calculated were the grain minor and major axial axes and the grain length leading to the determination of its size (in terms of volume).

The third stage consisted on the determination of an individual barley / malt variety density dependence law with grain size and the assessment of the grains weight percentage distribution. The steps taken on this stage consisted thus on the variety density function factor estimation and further multiplication on the individual grains volume for weight estimation. The density function factors were determined for each barley / malt variety given the initial correlations between the proposed IA method obtained size distribution and the standard method weight distribution. The grain size ranges studied in this work were the following: below 2.2 mm, 2.2 to 2.5 mm, 2.5 to 2.8 mm and above 2.8 mm in minor axis. Also the sum of the 2.5 to 2.8 mm and above 2.8 mm fractions (leading to an above 0.5 mm fraction) was studied being one of the most important parameters in the Supply Chain Management. The obtained results were thereafter plotted against the traditional standard EBC method results and their correlation studied.

3 Results and discussion

Regarding the robustness issue it could be verified that an error of only two pixels (0.13 mm) in the determination of the grains minor axial axis (± 2.5%) can propagate into an error of 15 to 20% in the determination of the estimated weight percentage of each barley / malt size fraction. The main factor regulating this dependence is the camera resolution (1600x1280 pixels), and it is expected that with the newly acquired higher resolution camera (3200x2600 pixels) the values will drop down to a maximum propagation error below 10%. It should be noticed, though, that the maximum propagation errors do not necessarily imply average final percentage differences of the same magnitude. In fact, during this work it was noted that the final absolute percentage differences did not surpass 5% in any case.

The analysis of sampling size also carried out revealed that for a subset down to around 200 grains (5 images) the results were still rather similar to the whole set analysis (550 grains from around 16 images). The absolute difference percentage between the whole set and the subset was shown to differ on 1.82% in average with a maximum up to 3.74% for the above 2.8 mm fraction of the *Esterel* barley variety. Most important, for the critical above 2.5 mm fraction the average error was only of 1.24% with a maximum absolute difference percentage of 1.92% in the *Prestige* variety. These results shows, thus, that the time and effort for obtaining the grains images in the field is feasible with a simple and fast method to evaluate the barley / malt grain size using 200 samples.

The size percentages for each barley / malt variety fraction were correlated to the standard method weight percentages showing a close precision between both methods. Indeed, the obtained correlation between the size and weight distribution percentages, prior to density correction, could be considered satisfactory (0.9489) with a regression error of 0.931. It would be expected that a perfect correlation should be obtained assuming a constant density regarding grain size, which in fact did not happen. A closer analysis to the results revealed that the density of at least one of the five varieties (*Esterel* barley) was far from being constant with the grain size, and two other grain types seemed to show also some dependence with size (*Scarlett* barley and *Esterel* malt). Therefore, the results obtained for the *Esterel* and *Scarlett* barleys and *Esterel* malt density correction factors allowed for the determination of the individual variety density and the proposed IA method weight correction. In fact, when determining the correlation between the corrected IA and standard methods weight percentages the obtained value raised to 0.9949 (with a 0.9836 regression error) as it can be seen in Figure 3.

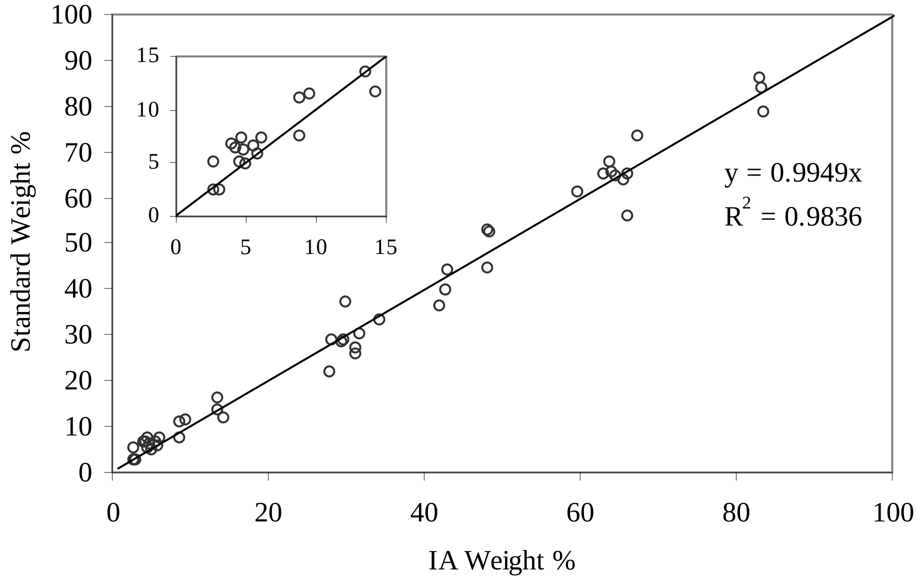

Figure 3 – Overall correlation between the image analysis (IA) procedure and standard method weight percentages.

Relating the proposed IA method weight distribution (after density correction) with the standard method respecting to each individual grain variety it was possible to determine both the percentages absolute difference, represented in Table I, and the correlations, represented in Figure 4, between the results of both methods.

Table I - Percentages absolute difference between the image analysis procedure and standard method weight percentages for the *Scarlett*, *Nevada*, *Esterel* and *Prestige* barley and *Esterel* malt for each studied fraction.

	Fractions (mm)				
	< 2.2	2.2 – 2.5	2.5 – 2.8	> 2.8	> 2.5
Scarlett	1.44	0.50	2.81	2.43	0.45
Nevada	0.66	2.46	4.17	4.16	2.42
Esterel barley	2.19	1.80	3.46	4.05	3.06
Esterel malt	1.32	1.11	1.81	2.92	1.28
Prestige	1.84	0.87	2.65	2.55	0.80
Average	1.49	1.34	2.98	3.22	1.60

With the obtained results one might expect that the overall weight percentages of the *Prestige* barley to be accurately determined by the proposed IA method, especially regarding the above 2.5 mm (0.45% difference) and below 2.2 mm (1.44% difference) fractions which are crucial to the business transactions selection. Furthermore, the attained 0.9882 correlation and the high regression coefficient of 0.9931 confirmed the quite good correspondence between the results of both methods. However caution is advisable concerning the weight distribution assessment within the above 2.5 mm fraction itself. After the density correction for the *Scarlett* barley regarding the above 2.5 mm (0.80% difference) and below 2.2 mm (1.84% difference) fractions the results were quite acceptable. That is confirmed also by the attained 1.0131 correlation with a regression coefficient of 0.9949. However it must be emphasize that the density function was deeply dependent on the grain size. Therefore and, keeping in mind the scarce number of data points available to determine the density function dependence, it is not licit to withdraw that the *Scarlett* barley can be accurately determined by the proposed IA method. Thus, only a more in-depth analysis with future field work values can provide a more reliable density function factors in order to validate the effectiveness of this method regarding the *Scarlett* barley. Concerning the *Esterel* and *Nevada* barleys and *Esterel* malt the obtained results do not allow, for the time being, a precise enough determination of the weight distribution by the proposed method.

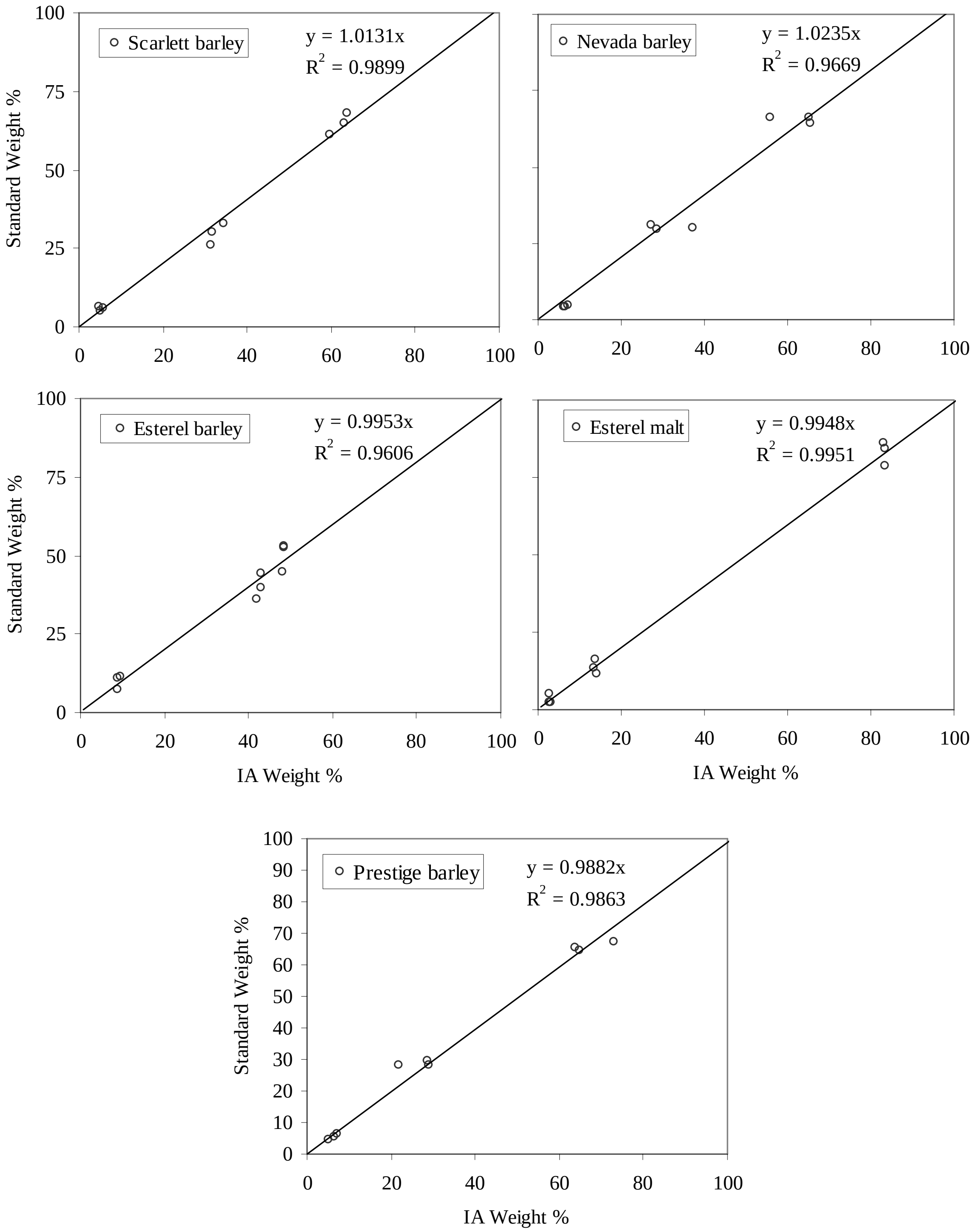

Figure 4 - Correlations between the image analysis procedure and standard method weight percentages for the *Scarlett*, *Nevada*, *Esterel* and *Prestige* barley and *Esterel* malt.

4 Conclusions

During this study it was found that the accuracy of the proposed IA method weight distribution was quite sensitive to the image resolution. Indeed, a relatively small error of 2.5% in the determination of the grains minor axial axis could propagate into a maximum error of 15 to 20% in the determination of the estimated weight percentage of each barley / malt size fraction. The acquisition of a higher resolution camera such as 3200x2600 pixels, however, could drop down these values to an error below 10%. One must keep in mind, though, that the maximum propagation errors do not necessarily imply average final percentage differences of the same magnitude such as it was proven b the fact that during this work the final absolute percentage differences did not surpass 5% in any case.

The analysis of sampling size carried out revealed that for a subset down to around 200 grains (5 images) the results were still rather similar to the whole set analysis with an absolute difference percentage between the two sets differing an average 1.82%. Furthermore, for the critical above 2.5 mm fraction the average error was only of 1.24% inferring that this method could be liable for a work field implementation to evaluate the barley / malt grain size by the acquisition of around 5 images per sample.

An initial analysis to both the proposed IA and standard methods weight percentages revealed that the density of the *Esterel* and *Scarlett* barleys as well as *Esterel* malt was far from being constant with the grain size. Therefore, a density function correction factor had to be estimated and further multiplied on the individual grains volume for weight estimation. These density function factors were then determined for each barley / malt variety given the initial correlations between the proposed IA method obtained size distribution and the standard method weight distribution.

After the correction of the proposed method weight values, size percentages for each barley / malt variety fraction were correlated to the standard method weight percentages showing a close precision between both methods. As a matter of fact, the obtained 0.9949 correlation between the size and weight distribution percentages (with a regression error of 0.9836), could be considered quite satisfactory. Furthermore, it could be found that for the *Prestige* barley the absolute difference between the results of the two methods were of 0.45% regarding the above 2.5 mm fraction and 1.44% regarding the below 2.2 mm fraction, crucial to the business transactions selection. After the density correction for the *Scarlett* barley absolute difference values were of 0.80% and 1.84% regarding respectively the above 2.5 mm and below 2.2 mm fractions.

Looking back to the ensemble of the afore-mentioned results it can be expected to accurately predict *Prestige* barley weight percentages distribution by the proposed IA method, especially concerning the crucial business transactions selection fractions. Regarding the *Scarlett* barley, the results could be considered as quite acceptable although caution is advisable on cause of the strong density function dependence on grain size. Therefore, at this point, it is not advisable to withdraw that the *Scarlett* barley can be accurately determined by the proposed IA method. Concerning the *Esterel* and *Nevada* barleys and *Esterel* malt the obtained results do not allow, for the time being, a precise enough determination of the weight distribution by the proposed method.

The results obtained by this studied opened great possibilities for the implementation of this method in the field. Indeed, progresses are already being made to put into action this methodology with small changes, namely on terms of a higher resolution acquisition camera (3600x2800 pixels) and the potential use of a camera adaptor to fit the black Bristol board.

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