ESTIMATION OF HOMOGENEITY STAGE OF BIOMASS MIXTURES
BIOMASAS MAISĪJUMU VIENDABĪGUMA PAKĀPES NOVĒRTĒŠANA

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Abstract. *Components of mixtures have to be in required proportion and homogeneous mixed to provide good quality (density, durability, and burning properties) of briquettes or pellets. For estimation of proportion of components and homogeneity several methods can be used: density of briquettes; durability of briquettes; proportion of the components in a determined volume; visual estimation. Visual estimation is a picture analyzing when quality tests through processing of digital pictures are performed. Standard deviation of the visual estimation of area occupied by mixture component particles does not exceed 5%. Standard deviation of the distance between straw particles has good correlation with increased peat proportion. Coefficient of determination is 0.98.*

Keywords: *Biomass mixtures, homogeneity, visual estimation.*

Introduction

As the fossil fuel resources are decreasing, in future we will have to rely on renewable energy sources. The main resources for solid biofuel in rural area of Latvia are residues of cereal crops, peat and emergent vegetation in lakes as common reeds (*Phragmites australis*). Straw more than 340 000 t annually can be used for heat production. Besides that more than 230 million tons of peat is available for biofuel production. To provide quality of biomass briquettes and pellets according Standards mixture of different biomass (straw and peat, reed and peat) can be used.

Components of composition have to be in required proportion and homogeneous mixed to provide good quality (density, durability, and burning properties) of briquettes or pellets. Components of granular mixtures vary in terms of grain dimensions, density, shape, humidity etc. Those factors have an important influence on the segregation phenomenon concurrent with mixing process. Homogeneity of mixture is the keystone in selection process of the mixer type for biomass materials. To define proportion of components in granular mixtures and homogeneity several methods can be used:

- ✓ Density measuring of briquettes or mixture – can be used if components of mixture are various in densities and changes in proportion of components let detect changes of density in determined volume of biomass;
- ✓ Durability measuring of briquettes – if changes of component substantially influences durability (shear test, other strength parameters) of briquettes then it could be a qualitative indicator of quality (proportion and homogeneity) of mixture;
- ✓ Proportion measuring of the components in a determined volume – if the components particles is easy to separate from each other then the mass of component is precise indicator of mixture quality;
- ✓ Visual estimation – computer based picture analyzing methods. Visual estimation is a picture analyzing when quality tests through processing of digital pictures are performed. It could be realized in different ways, for example, the area occupied by particles can be determined or distance between particles can be analyzed.

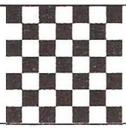
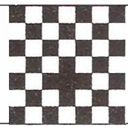
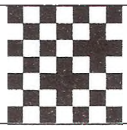
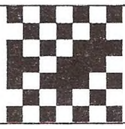
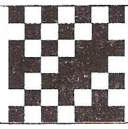
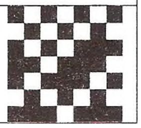
The visual estimation (image processing) of biomass compositions could be good solution for quality assessment of different color and tonality components mixture. Important condition for high precision of estimation is the system calibration. The methods of calibration and results of image processing of different biomass mixtures using Matlab software is described in the article.

Materials and methods

Evaluation of visual estimation system was done by imitative picture made in graphical software. The basic test area contains 49 squares: 25 black and 24 white (Tab. 1). In the every next sample was added one black square. Precision of visual estimation method for measuring area ratio between white squares and total area was defined by manually calculated area ratio.

Table 1.

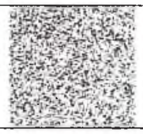
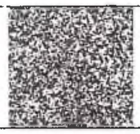
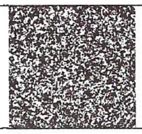
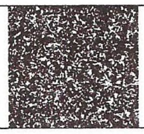
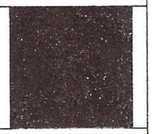
Estimation of system

Number of sample	1	2	3	4	5	6	7
Type of sample							

To evaluate precision of visual estimation of peat and straw mixtures for briquetting the specific mixtures were tested. Six different mixtures were made from chopped straw and peat: 100% straw; 80% straw 20% peat; 60% straw 40% peat; 40% straw 60% peat; 20% straw 80% peat; and 100% peat (Table 2.). Particle size of components was 1 – 2 mm. Moisture of components 12%. Mixing of components was done by hands till consummation of homogeneous mixture.

Table 2.

Samples of peat and straw mixtures

Number of sample	1	2	3	4	5	6
Image of sample						
Peat proportion, %	0	20	40	60	80	100

Mixtures were scanned by regular picture scanner and as the result one size (75 × 70 mm) and one resolution (200 dpi) pictures were obtained. To increase contrast of mixture components in the pictures, they were changed in one way using software *Corel-PhotoPaint* and after that saved in file type **.png*. Picture analyzing was done by software *Matlab-Simulink*. *Matlab* functions used for image analyzing process is showed and explained in the Table 3.

In this case background is area set by darker particles i.e. peat particles, but light particles what characterize mixture and are further analyzed are straw particles. Pictures were converted to binary image where each pixel assumes one of only two discrete values: 1 or 0. Forward variable name BW is used to refer the binary images.

D1=*bwdist(bw,'euclidean')* computes the Euclidean distance transform of the binary image BW. For each pixel in BW, the distance transform assigns a number that is the distance between that pixel and the nearest nonzero pixel of BW. bwdist uses the Euclidean distance metric by default. BW can have any dimension. D is the same size as BW.

The function *bwdist* supports several distance metrics, listed in the following Table 4.

Standard deviation of distance transform for columns of pixels in the picture is calculated by *Matlab*. To get overall view about the picture (mixture) average of the standard deviations was calculated.

Table 3.

Explanation of used Matlab functions [2]

I = *imread('salmi_100.png')*	Read and display the image with name "salmi_100" and file type *.png
background = *imopen(I, strel('disk', 200))*	Estimation the value of background pixels.
I2 = *imsubtract(I,background)*	Subtract the background image from original image.
I3 = *imadjust(I2)*	To adjust the contrast of the image.
level = *graythresh(I3)*	This function automatically computes an appropriate threshold to use to convert the grayscale image to binary.
bw = *im2bw(I3,level)*	Function performs the conversion.
figure, *imshow(bw)*	This function displays the black and white image.
[labeled,numObjects] = *bwlabel(bw,4)*	This function determines the number of objects.
graindata = *regionprops(labeled,'basic')*	This function measures objects or region properties in an image and returns them in a structure array.
D1=*bwdist(bw,'euclidean')*	Computes the distance transform.
y = *std(D1)*	Standard deviation of distance transforms in one column of the pixels.
mean(y)	Mean of the standard deviations.
whos	Gives information about variables in the workspace.
G=*sum([graindata.Area])*	Gives value of area occupied by one component particles.

Second parameter obtained from the pictures was ratio of nonzero pixel occupied area and background (whole picture) area. If this method satisfies the requirements then ratio of area have to match with percentage of component.

Standard deviation of area ratio can be calculated:

$$S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - p)^2} \qquad (1)$$

where: x_i – obtained ratio of area;

p – theoretically obtainable ratio of area;

n – the number of examples.

Standard deviation served to determine the degree of mixing based on Rose's formula [1]:

$$M = 1 - \frac{S}{S_0} \quad (2)$$

where:

$$S_0 = \sqrt{p(1-p)}\,. \quad (3)$$

Table 4.

Distance Metric [2]

Distance Metric	Description	Illustration: Description	Illustration: Distance transform
Euclidean	The Euclidean distance is the straight-line distance between two pixels.	In 2-D, the chessboard distance between (x_1, y_1) and (x_2, y_2) is $\max\left(\lvert x_1 - x_2\rvert, \lvert y_1 - y_2\rvert\right)$	1.41 1.0 1.41 1.0 0.0 1.0 1.41 1.0 1.41
City Block	The city block distance metric measures the path between the pixels based on a 4-connected neighborhood. Pixels whose edges touch are 1 unit apart; pixels diagonally touching are 2 units apart.	In 2-D, the cityblock distance between (x_1, y_1) and (x_2, y_2) is $\lvert x_1 - x_2\rvert + \lvert y_1 - y_2\rvert$	2 1 2 1 0 1 2 1 2
Chessboard	The chessboard distance metric measures the path between the pixels based on an 8-connected neighborhood. Pixels whose edges or corners touch a 1 unit apart.	In 2-D, the Euclidean distance between (x_1, y_1) and (x_2, y_2) is $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ This is the default method.	1 1 1 1 0 1 1 1 1
Quasi-Euclidean	The Quasi-Euclidean metric measures the total Euclidean distance along a set of horizontal, vertical, and diagonal line segments.	In 2-D, the quasi-Euclidean distance between (x_1, y_1) and (x_2, y_2) is $\lvert x_1 - x_2\rvert + (\sqrt{2} - 1)\lvert y_1 - y_2\rvert$ $if\ \lvert x_1 - x_2\rvert > \lvert y_1 - y_2\rvert$ $(\sqrt{2} - 1)\lvert x_1 - x_2\rvert + \lvert y_1 - y_2\rvert$ $if\ \lvert x_1 - x_2\rvert < \lvert y_1 - y_2\rvert$	2.8 2.2 2.0 2.2 2.8 2.2 1.4 1.0 1.4 2.2 2.0 1.0 0 1.0 2.0 2.2 1.4 1.0 1.4 2.2 2.8 2.2 2.0 2.2 2.8

Results and discussion

To test the precision of visual estimation system area ratio between white pixels and total area of imitative image was calculated manually and compared with the area ratio obtained by image analyzing. Fig. 1 shows difference between images analyzes and manually calculated data of area ratio for pictures from Table 1. Maximal relative error of those data is less than 1% and could be prevent with more particular measuring of image.

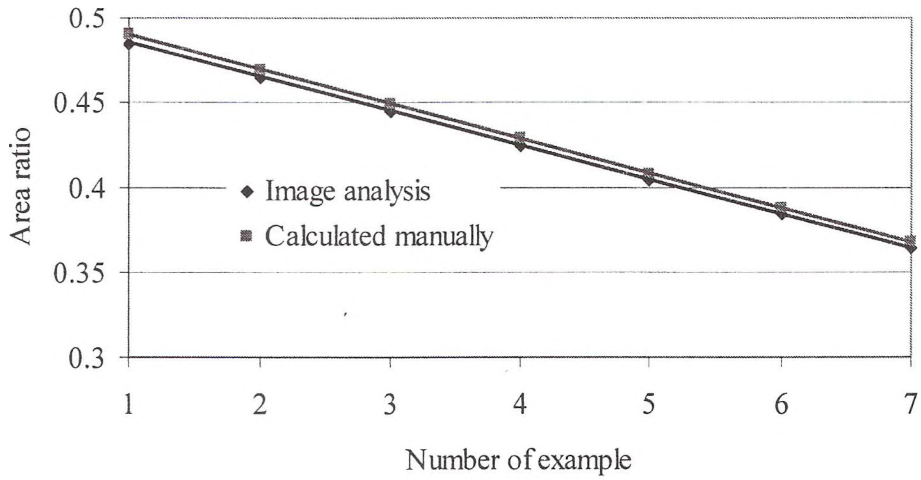


Fig.1. **Estimation of system**

Growing of standard deviation of distance consistently grows with dispersion of distances between nonzero pixels or white particles. Changes of area ratio of 25% change the standard deviation about 50%.

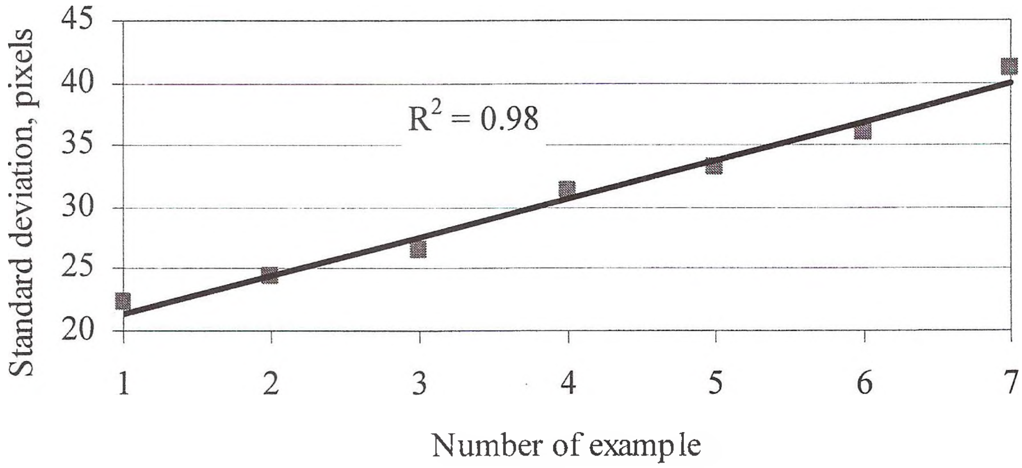


Fig.2. **Standard deviation of distances between particles**

Results of peat and straw mixtures analyze are showed in Fig. 3. In general, the results are close for image analyze and theoretically obtainable data. Deviation from theoretical line increases when straw proportion comes close to 100% and peat proportion comes close to 100%. It depends on specific character of color transform of images: conversion of straw picture to black and white image did not give 100% white color similarly with peat there were approximately 7% difference of average values (theoretically and image analyze).

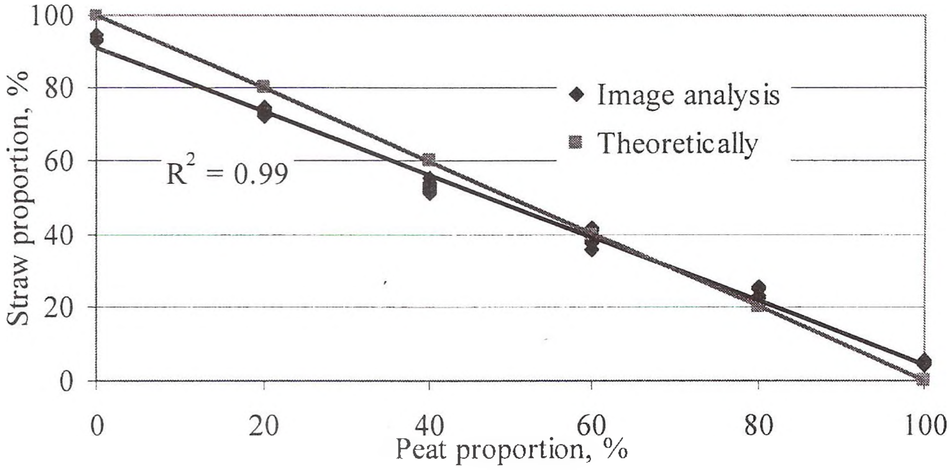


Fig.3. **Comparison data of Image analyze and theoretical data**

Error of color transform can be substantially decreased by calibration of system and precise selection of white and black levels on image transformation (Fig. 4). Standard deviation of the data does not exceed 5%. This is acceptable indicator for biomass material where homogeneity of mixture depends on so many parameters: particle size, dispersion of particle size, particle size ratio of components, density of particles, moisture of components, and other bulk properties. High influence of data accuracy gives particle orientation, if they are thin and long, then area of particle lateral area is much larger than area of the ends.

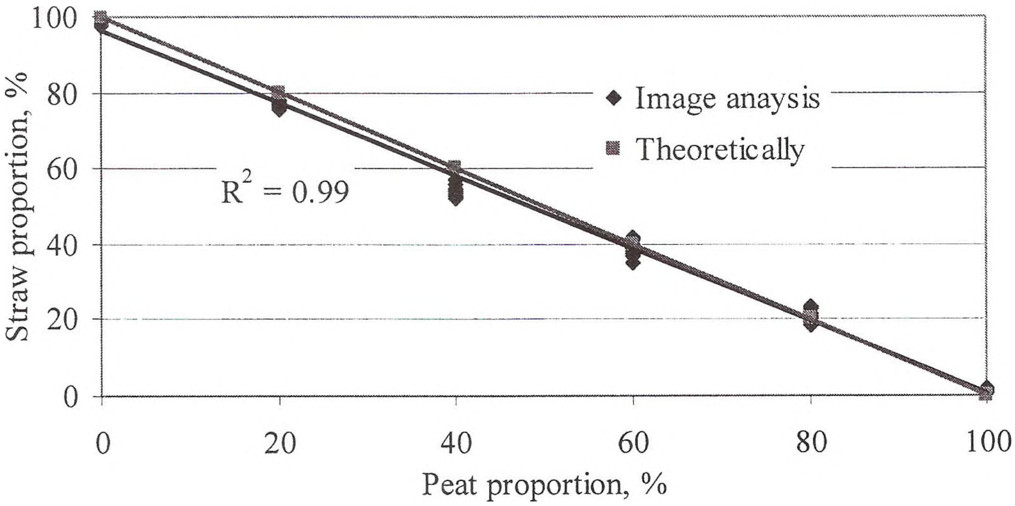


Fig.4. **Comparison adjusted data of Image analyze and theoretical data**

Standard deviation of the distance between straw particles has good correlation with increased peat proportion (Fig. 5). Coefficient of determination is 0.98. Considering that for those experiments homogeneous mixtures were used (Figure 5) for mixture quality described before assessment can be applied. For example if peat proportion is 20% than standard deviation of Euclidean distance transform have to be approximately 0.5 for homogenous mixture.

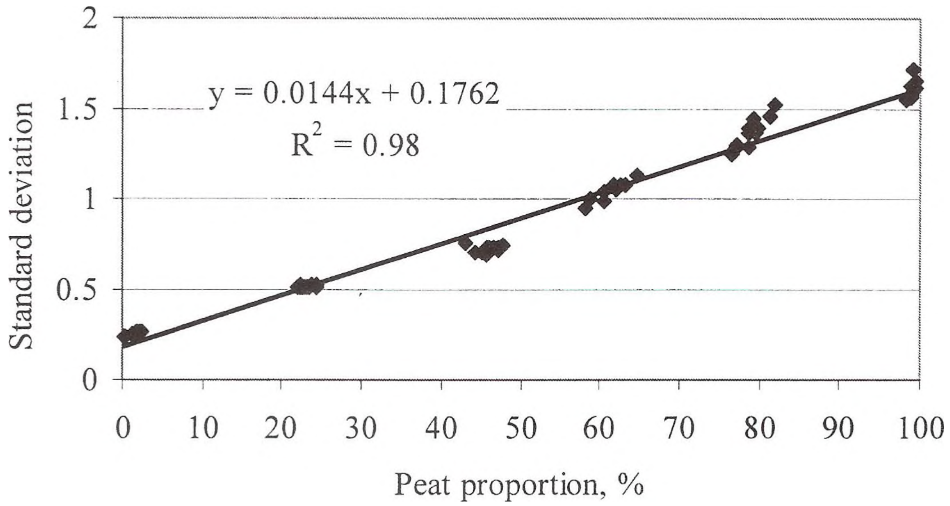


Fig. 5. **Standard deviation (pixels) of the distance between straw particles in dependence on peat proportion**

To estimate influence of picture resolution on standard deviation of distance between straw particles and mixture proportion in software Corel Photo Paint the resolution of the picture was changed from 200 to 20 dpi. For fixed straw proportion of the mixture (straw 60% and peat 40%) standard deviation changes from 0.53 to 0.73 on dependence of image resolution (Fig. 6). It shows that resolution of picture is important parameter in visual estimation process.

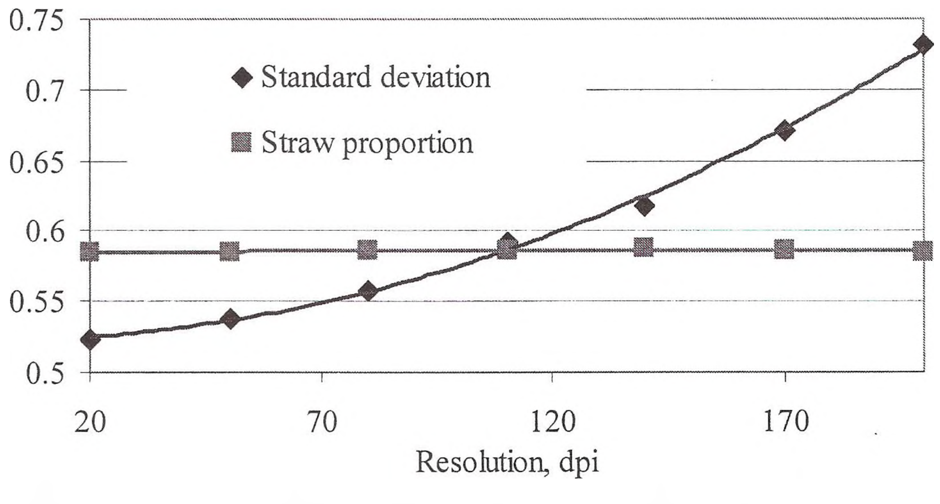


Fig.6. **Changes of standard deviation and mixture proportion in dependence on picture resolution**

Conclusions

1. Homogeneity of mixture depends on many parameters: particle size, dispersion of particle size, particle size ratio of components, density of particles, moisture of components, and other bulk properties.
2. Visual estimation of area ratio of mixture components is recommended to define the proportion of mixture components. Standard deviation of the visual estimation of area occupied by mixture component particles does not exceed 5%.

3. Standard deviation of the distance between straw particles has good correlation with increased peat proportion. Coefficient of determination is 0.98. Standard deviation of the distance between straw particles is recommended to define homogeneity of mixture.
4. Standard deviation changes from 0.53 to 0.73 if resolution of picture changes from 200 to 20 dpi. Resolution of picture is important parameter in visual estimation process.

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References

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