Barbara RABA, Krzysztof NOWAKOWSKI, Piotr BONIECKI
Poznań University of Life Sciences, Institute of Biosystems Engineering
ul. Wojska Polskiego 50, 60-637 Poznań, Poland
e-mail: braba@up.poznan.pl

VISUAL QUALITY EVALUATION OF MALTING BARLEY WITH USE OF NEURAL IMAGE ANALYSIS

Summary

The quality evaluation is one of the most important stages of the production processes. The same as regards the beer production and its components: hop, yeast, malting barley and other ingredients. Presented project deals with the complex quality evaluation of malting barley used for malt production. Its main goal is to elaborate complete methodology for the identification of varieties, the level of contamination and other visual features of malting barley with the use of computer science technologies, such as neural image analysis.
***Key words**: malting barley, image processing, artificial intelligence*

WIZUALNA OCENA JAKOŚCI JĘCZMIENIA BROWARNEGO Z WYKORZYSTANIEM NEURONOWEJ ANALIZY OBRAZU

Streszczenie

Jednym z najważniejszych etapów w procesie produkcyjnym jest ocena jakości. Podobnie jest w produkcji piwa i jego składników: chmielu, drożdży, jęczmienia browarnego i innych. Przedstawiony projekt dotyczy kompleksowej oceny jakości jęczmienia browarnego używanego do produkcji słodu. Jego głównym celem jest opracowanie kompletnej metodyki identyfikacji odmian, poziom zanieczyszczenia i innych wizualnych cech jęczmienia browarnego z wykorzystaniem technologii informatycznych opartych na neuronowej analizy obrazu.
***Słowa kluczowe**: jęczmień browarny, przetwarzanie obrazu, sztuczna inteligencja*

1. Introduction

New technologies are entering the subsequent sectors of industry. It is followed by computerization and automation of production processes, wherever it is possible to replace human labor. The main goal is to improve the production processes, to produce more efficiently and, at the same time, maintain the quality and the costs of generated products [1, 6, 7, 8, 9]. Those changes also concern food industry. One of its branches, developing dynamically, is beer production. The final product should fulfill certain parameters, which should meet consumer tastes. The high quality of the product determines the improvements in technologies of producing the ingredients. One of the components used for beer production is malting barley (Fig. 1), or rather malt extracted from special varieties of barley [4].

Source: own work / Źródło: opracowanie własne

Fig. 1. The grains of malting barley
Rys. 1. Ziarniaki jęczmienia browarnego

The malting barley is dedicated only for the malt industry. The malting barley varieties should comply strict specification:
- Germination % min. 97% after 3 days
- Water content: 12.0%, max. 13.0%
- **Low protein content: 9.0% to 11.5%** (no use for feed production)
- Micro-organisms below a set level
- Pesticide residues according to national law
- **Variety purity min. 99%** [4]**.**

Highlighted parameters are the most important for the malt production. The higher protein content slows down the relaxation of grain (stage of manufacture of the grist) and reduces the efficiency of the malt extract. The variety purity determines the type of the produced malt. The malt-houses mix selected types of malt to obtain the special kind of grist ordered by the breweries.

The characteristic of the grains received straight from the farmers are evaluated by the highly qualified workers of the malt-houses. Initial stage of the assessment is the selection of the representative samples from the bought crops. Then in the laboratory starts the quality evaluation: visual and biochemical. The whole visual evaluation is the manual segregation, carried out by malt-house laboratory staff. In this project we focused exactly on the visual assessment which included: contamination, the hue of grains and the barley variety. Every of this feature is generating huge difficulties for identification. For contamination of the barley there are standards: PN-R-74109 and PN-R-74110 (Polish standards). It helps to identify the groups of grains, for example: broken grain, grains with removed germ. All in all, there are doubts of grains qualification, due to the subjectivity of the laboratory workers and the impact on the work – the human factor – tiredness. Additionally there are no specified key standards which can help differs varieties of malting barley. Malt-houses and specialized laboratories are developing their own standards for grains distinguishing. Nowadays they are using the chemical checks of the malt parameters for the acknowledgement of the variety.

The main purpose of presented project is to work out the algorithms for the image analysis and choose the optimal model or models of artificial neural networks (ANN). This technology may solve problems of varieties recognition and calculation of the level of contamination, close or even better than human abilities. Fine results can lead to the automation of the visual grains evaluation process.

2. Material and methods

Project realised at the Poznan University of Life Sciences is divided into two parts: variety identification and the assessment of the level of grains contamination. In this article we present the methodology used in the first part of the project – the variety distinguishing. The skeleton of the methodology (Fig. 2) is based on the methodologies used for neural image analysis of corn kernels, rape seeds (research at Poznan University of Life Sciences, Poland).

In presented project we tried to distinguish between tree spring varieties from year 2011: Beatrix, Sebastian and Xanadu. Selected barley varieties are quite common in theirs specification (Tab. 1) used for malt obtaining.

1) Collect the representative samples of the analysed grains
- Grains undamaged, without diseases

2) Image acquisition of the malting barley grains
- Dedicated test station for image acquisition: lighting fitting and camera

3) Processing and image analysis with the dedicated software
- The use of specialized software for image processing

4) Choosing the representative features: geometrical and non-geometrical
- Example: area, circumference, colour, texture

5) Conversion received information to format of learning set of data
- Prepare obtained data for conversion into numerical data used in learning of artificial

6) Data analysis (with MATLAB – Neural Network Toolbox)

7) Choosing optimal model/models of neural network

8) Verification and validation of chosen model/models

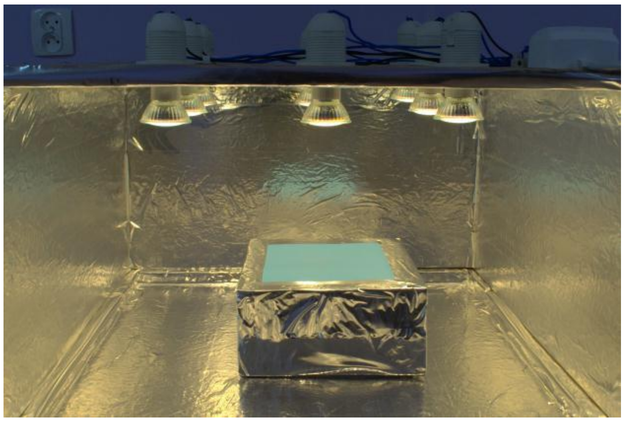
Source: own work / Źródło: opracowanie własne

Fig. 2. The scheme of the methodology used in presented project
Rys. 2. Schemat metodyki zastosowanej w projekcie

Table 1. Specification of the chosen barley varieties [3]
Tab. 1. Specyfikacja wybranych odmian jęczmienia browarnego [3]

Specification	Variety		
	Beatrix	Sebastian	Xanadu
	[scale: 9˚]		
Brewing quality	5,10	6,85	6,70
Extractivity	3	7	7
Viscosity of the wort	7	7	7
Kolbach's no.	7	6	6

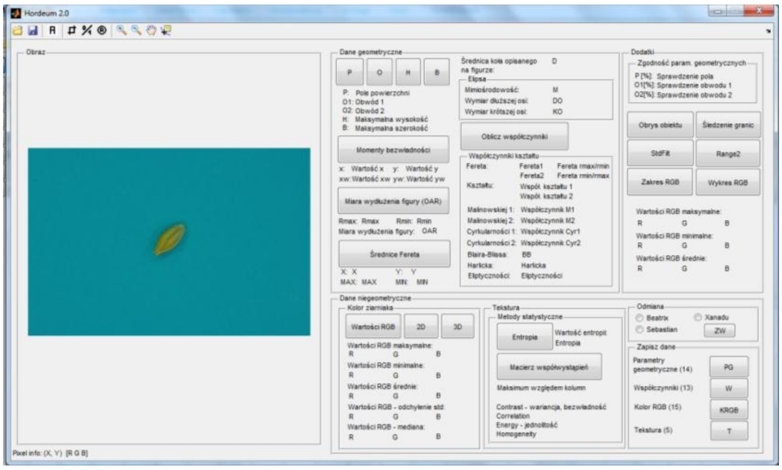
The first stage of the project was to select representative samples of the barley grains for the image acquisition. We choose 700 grains from each barley variety, which comply rough requirements: no mechanical damages and no diseases (exc. *fusarium* - fungi). The grain images were done in special test stand (Fig. 3). The stand has its own light source: eight LED light bulbs (color temperature similar to daylight) with luminance 5,6klx (all bulbs enabled). Image acquisition was carried out with the camera Nikon D90 with lens: AF-S Nikkor 18-70 mm 1:3,5-4,5G ED with the magnification of 8 (2 rings 67 mm, +2, +4).



Source: own work / Źródło: opracowanie własne

Fig. 3. The test stand for the image acquisition used in the project
Rys. 3. Stanowisko testowe do akwizycji obrazów

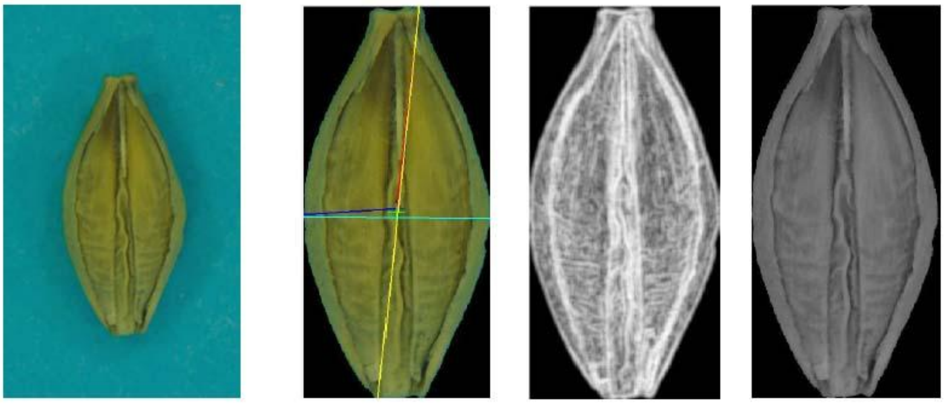
The next step was to process and analyse obtained images with the use of dedicated authors' software – 'Hordeum 2.0' (Fig. 4). The software was created with use of the Matlab 2011b. 'Hordeum 2.0' gets the information of the features (Fig. 5) of the grains from the images and then processes them through models of neural networks with use of additional toolbox of MATLAB – Neural Network Toolbox. For processing we chose 200 from 700 images of each variety (best quality for image analysis), in total we got 600 pictures of three varieties. Each picture provided 46 variables [2]:
- geometrical: area of the grain, circumference, height, width, moments of inertia, Feret's diameters, radius from the centre of gravity (maximum and minimum), aspect ratio and the dimensionless quantities – factors: Feret, Shape, Malinowska, Circularity, Blair-Bliss, Haralic, Ellipticity [10],
- non-geometrical: colours (values: maximum, minimum, mean, median, standard deviation), texture (entropy, co-matrix coefficients).



Source: own work / Źródło: opracowanie własne

Fig. 4. The authors software 'Hordeum 2.0'
Rys. 4. Autorski system 'Hordeum 2.0'

Obtained data from the images were adapted to the sets of data used for the artificial neural network.

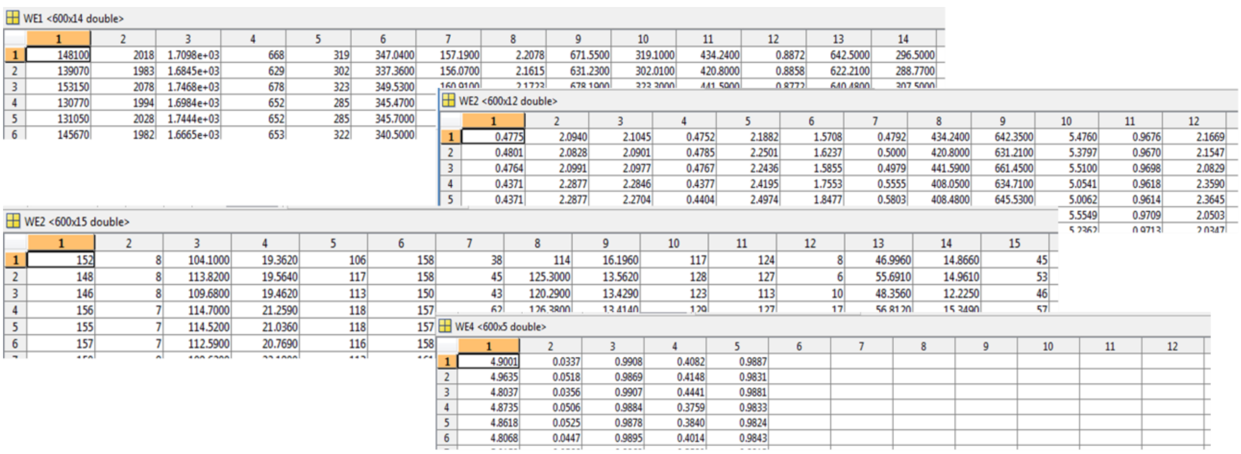


Source: own work / Źródło: opracowanie własne

Fig. 5. The results of the algorithms used in the authors software 'Hordeum 2.0'
Rys. 5. Wyniki działania algorytmu wykorzystanego w systemie 'Hordeum 2.0'

3. Results / conclusions

Created software 'Hordeum 2.0' allowed to obtain data for learning processes of artificial neural networks [11]. In project we divided 46 variables into 4 sets of data (Fig. 6): geometrical parameters (14), factors (12), colour values (15) and texture coefficients (5). With the use of the Neural Network Toolbox, we tried to find model or models of neural networks which would classify the variety of malting barley.



WE1 <600x14 double>

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	148100	2018	1.7098e+03	668	319	347.0400	157.1900	2.2078	671.5500	319.1000	434.2400	0.8872	642.5000	296.5000
2	139070	1983	1.6845e+03	629	302	337.3600	156.0700	2.1615	631.2300	302.0100	420.8000	0.8858	622.2100	288.7700
3	153150	2078	1.7468e+03	678	323	349.5300	160.9100	2.1723	678.1900	323.3000	441.5900	0.8772	640.4800	307.5000
4	130770	1994	1.6984e+03	652	285	345.4700								
5	131050	2028	1.7444e+03	652	285	345.7000								
6	145670	1982	1.6665e+03	653	322	340.5000								

WE2 <600x12 double>

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.4775	2.0940	2.1045	0.4752	2.1882	1.5708	0.4792	434.2400	642.3500	5.4760	0.9676	2.1669
2	0.4801	2.0828	2.0901	0.4785	2.2501	1.6237	0.5000	420.8000	631.2100	5.3797	0.9670	2.1547
3	0.4764	2.0991	2.0977	0.4767	2.2436	1.5855	0.4979	441.5900	661.4500	5.5100	0.9698	2.0829
4	0.4371	2.2877	2.2846	0.4377	2.4195	1.7553	0.5555	408.0500	634.7100	5.0541	0.9618	2.3590
5	0.4371	2.2877	2.2704	0.4404	2.4974	1.8477	0.5803	408.4800	645.5300	5.0062	0.9614	2.3645
6										5.5549	0.9709	2.0503
7										5.2362	0.9713	2.0347

WE2 <600x15 double>

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	152	8	104.1000	19.3620	106	158	38	114	16.1960	117	124	8	46.9960	14.8660	45
2	148	8	113.8200	19.5640	117	158	45	125.3000	13.5620	128	127	6	55.6910	14.9610	53
3	146	8	109.6800	19.4620	113	150	43	120.2900	13.4290	123	113	10	48.3560	12.2250	46
4	156	7	114.7000	21.2590	118	157	62	126.3800	13.4140	129	127	17	56.8120	15.3490	57
5	155	7	114.5200	21.0360	118	157									
6	157	7	112.5900	20.7690	116	158									

WE4 <600x5 double>

	1	2	3	4	5	6	7	8	9	10	11	12
1	4.9001	0.0337	0.9908	0.4082	0.9887							
2	4.9635	0.0518	0.9869	0.4148	0.9831							
3	4.8037	0.0356	0.9907	0.4441	0.9881							
4	4.8735	0.0506	0.9884	0.3759	0.9833							
5	4.8618	0.0525	0.9878	0.3840	0.9824							
6	4.8068	0.0447	0.9895	0.4014	0.9843							

Source: own work / Źródło: opracowanie własne

Fig. 6. Sets of variables used in Neural Network Toolbox (Matlab)
Rys. 6. Zbiór zmiennych wykorzystany w Neural Network Toolbox (Matlab)

Processing the sets of data, with mentioned Matlab Toolbox, gave the results presented in Tab. 2. Comparing those 4 obtained neural network models we observed that the optimal model for variety recognition was with the third set of data – colour values (optimal model of neural network in Fig. 7). The reason is no connection with the geometrical features of the grains. In research we used barley grains which were not segregated in terms of size. This resulted in the fluctuations of the geometrical grains features. It can be a reason of such high level of errors (learning, validation, testing).

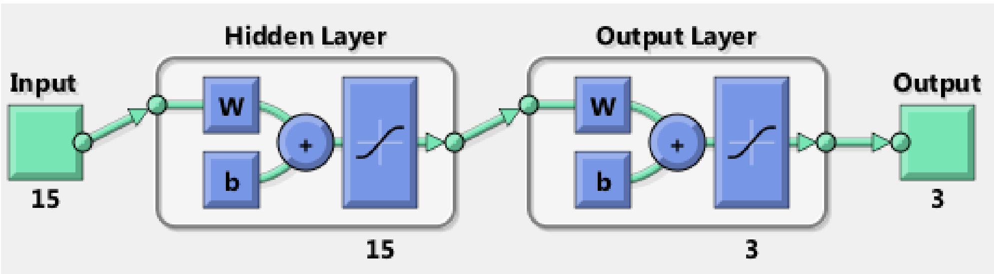
After initial research we may suppose that colour variables can be the solution for classifying barley varieties, used in the project research. To get better results there should be used more cases of learning sets for ANN – more image acquisition. We also may modify the data sets to choose some of the most meaningfully variables that best differentiate the barley varieties.

The received results are sufficiently good to enough to deal with the further research in presented area. Chosen optimal model would be implemented into software for rapid identification of the variety. Of course there should be more varieties of barley used for further research.
For now on, only manual identification of varieties and estimation of contamination level (classification of grains) or chemical identification are implemented in the malting industry. Combining artificial neural networks and image processing into neural image analysis, may solve problem of process repeatability because of the human factor (tiredness and subjectivity of malt-house workers) and may accelerate the process of malting barley evaluation. It may bring the concrete gains for the malt-houses and it will affect the quality of the beer production. Also it may improve the method of the barley assessment in relation to the crop producers. There will be fair conditions for the barley evaluation.

Table 2. The initial results of neural network processing obtained in Neural Network Toolbox
Tab. 2. Wyniki działania sztucznej sieci neuronowej w Neural Network Toolbox

Model specifications	**Set of data**			
	Geometrical parameters	**Factors**	**Colour values**	**Texture coefficients**
The best model of neural network	MLP 14:14-18-3:3	MLP 12:12-11-3:3	MLP 15:15-15-3:3	MLP 5:5-13-3:3
Quality of learning	0,670	0,573	0,967	0,647
Quality of validation	0,660	0,593	0,952	0,633
Quality of testing	0,567	0,587	0,949	0,680
Learning error	0,393	0,420	0,120	0,392
Validation error	0,400	0,422	0,122	0,410
Testing error	0,434	0,428	0,135	0,377

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 7. The best model of neural network for variety identification – MLP 15:15-15-3:3
Rys. 7. Najlepszy model sztucznej sieci neuronowej do identyfikacji odmian – MLP 15:15-15-3:3

4. References

[1] Boniecki P., Nowakowski K.: Klasyfikacja ziarniaków kukurydzy w oparciu o neuronową identyfikację kształtu. Journal of Research and Applications in Agricultural Engineering, 2008, vol. 53(3), 14-17.
[2] Boniecki P., Nowakowski K., Przybylak A.: Neuronowa kompresja danych graficznych w procesie identyfikacji wybranych obiektów rolniczych. Journal of Research and Applications in Agricultural Engineering, 2009, vol. 54(2), 19-23.
[3] COBORU TABLES.: The list of varieties – agricultural plants 2011, Table 5, 32 COBORU, 2011.
[4] Lewis M. J., Young T. W.: Brewing, PWN, 2001.
[5] Nowakowski K.: Metody pozyskiwania zbiorów uczących dla modelu neuronowego identyfikującego uszkodzenia ziarniaków. Technika Rolnicza Ogrodnicza Leśna, 2007, (4/2007), 6-8.
[6] Nowakowski K., Boniecki P., Dach J.: Neural image analysis in identification process of mechanical damages of kernels. Journal of Research and Applications in Agricultural Engineering, 2009, vol. 54(2), 77-80.
[7] Nowakowski K., Boniecki P., Dach J.: The identification of mechanical corn kernels damages basis on neural image analysis. Proc. IEEE Computer Society, 2009, 412-415, DOI:10.1109/ICDIP.2009.78
[8] Nowakowski K., Boniecki P., Tomczak R.J., Raba B.: Identification process of corn and barley kernel damages using neural image analysis, 2011, Proc. SPIE 8009, 800908; doi:10.1117/12.896184
[9] Nowakowski K., Boniecki P., Raba B.: Image analysis and neural networks in the process of identifying of selected mechanical damage maize caryopses. Journal of Research and Applications in Agricultural Engineering, 2011, vol. 56(1), 100-102.
[10] Osowski S.: Neural networks to processing of information. Publishing house of Warsaw Technical University, Warsaw, 2000.
[11] Tadeusiewicz R., Korohoda P.: Computer analysis and image processing, Telecommunications Advancement Foundation Publisher, 1997.