The Improvement of the Wort Manufacturing Processes

Simonffy Arpad, Ţîţu Aurel Mihail and Marinescu Niculae Ion

***Abstract* — In beer manufacturing we can distinguish a few important manufacturing processes, such as the process of malt manufacture, the process of wort manufacture, the process of beer fermentation, the process of beer filtration and stillness, the process of bottling the beer.**

According to the experience of the most important specialists in the world, in a brewery the most important section that determines the quality and the quantity of the beer produced is the Brewhaus section. It is in this section that the wort is being produced and then after dosing the yeast of inferior fermentation, - because in this paper we resume strictly to beer manufacturing with this type of yeast – the process of fermentation, filtration and bottling the final product is being obtained, the beer.

Still the experience of producing beer for hundreds of years proved to us that since we manage to produce wort within some qualitative and quantitative parameters as constant as possible, that means it is easier and safer to obtain a finite beer product within very good constant qualitative parameters and also profitable from the economic point of view.

Taking into consideration all these important conclusions, I started the experiments in the process of wort manufacture in order to try to improve, to optimize the processes of wort manufacture in such a way that, as a result of my improvements, any specialist working in this field of beer manufacturing, wort production, with the actual plants could obtain the wort within the constant qualitative and quantitative parameters as required by the technical indication of the type of wort that is being produced so that the beer production nowadays be qualitatively as good as possible, economically as profitable as possible and environmentally with an impact as insignificant as possible.

***Index Terms* — barley malt, brewing water, wet milling, mash tun, mash saccharification diagram, the ph value of the mash, Lauter tun, mash filtration, first wort, extract looses, spain grains, sparging, weak water, wort kettle, evaporation rate, boiled wort, internal wort boiling, hop, wort rupture, full kettle, Whirlpool, hot trub separation, wort cooling, wort aeration, cold wort.**

I. Short presentation of beer manufacturing history

No matter where we want to search about the origin or the first beer production, all data found in the books of specialized authors, data that can be found on the internet as well, indicate that the beer was produced for the first time in around 6000 – 4000 i.Hr. All these documents certify that beer was produced for the first time in the Ancient Egypt, but there is evidence that in the same period in Iraq or Syria there were also found documents that argument this thing.

„For a long time it was believed that the first beer was produced in the Ancient Egypt, but at the beginning of the XXth century there were made some archaeological discoveries and they indicated Sumer as being the place where beer was produced for the first time.

Source:
http://historia.ro/exclusiv_web/general/articol/originea-berii - Author: Mihai Dreagnea

One of the most famous monasteries to manufacture beer was the Monastery near Freising (Germany) named Weihenstephan where starting with the IXth century beer used to be boiled and where over one hundred monks dealt with beer manufacturing.

In the history of beer manufacturing the year 1516 is very important because at that time in Bavaria there was proclaimed the "Reinheitsgebot", that is the law of pure beer manufacturing and according to which beer could be made only of malt, hop, and water. From now on the center of beer manufacturing moved in Bavaria and Thuringia where there still were a lot of small breweries that could comply with this law.

In the XIXth century the malt and beer production switched to industrial production and thus the great holdings of beer manufacturing began to appear. Usually on the territory of the brewery there were built the malt factories; thus, throughout the year the malt and beer factory had a constant activity because the malt could be produced in winter at its best and the beer consumption used to increase a lot in summer.

In the last decades of the XXth century the beer industry globally recorded important progress regarding the technology and the technical equipment, with new types of plants and installations that resulted in the improvement of the beer quality.

Short presentation of the World, European, Romanian beer market - The first four great beer producers in the world – Anheuser- Busch, InBev, SABMiller, Heineken and Carlsberg – control more than half of the type market. On the fifth place there is the Chinese company Taingtao Brewery.

"On a global level, the growth from 2011 indicates a slight economic recovery and represents a significant improvement compared to the growth of 1,6% recorded in 2010 and 0,4% in 2009, respectively", declared the manager Plato Logic, Ian Pressnell.

Last year the classification of the best brewers did not change at all, Anheuser Busch InBev continued to be the leader whereas SABMiller, Heineken and Karlsberg came

Manuscript received December 30, 2013; revised January 27, 2014. This work was supported in part by Arpad SIMONFFY, Mihail Aurel TITU from Lucian Blaga University of Sibiu Romania and Niculae Ion MARINESCU from Politehnica University of Bucharest.

Arpad SIMONFFY is Ec. Sc.D. Student at "Lucian Blaga" University of Sibiu and is the Manager of the Sebes Brewery.

Mihail Aurel ŢÎŢU is Professor at "Lucian Blaga" University of Sibiu (Faculty of Engineering) and is Director of the Intellectual Property Department of the University and Director of the European PATLIB Centre (corresponding author to provide phone: +40269430110, e-mail: mihail.titu@yahoo.com).

Niculae Ion MARINESCU is Professor at "Politehnica" University of Bucharest.

second. These ones have a total market share of 50% at a world level.

Source: http://www.magazinulprogresiv.ro/stire/3001/Piata_mondiala_a_berii_a_crescut_cu_2_7_in_2011.html

The beer appetite of the planet's inhabitants records a continuous growth. At least this results from a recent report ordered by Kirin Holdings. The data are impressive: 2011 was the 27th consecutive year marking the growth of the global production . A production that reached 192.656.500 tons, which means a growth of 3,7% compared to 2010.

The growth was supported first of all by China, which is the greatest producer in the world (around 25% from the total production) for the 10th consecutive year. Also, a growth of the beer volume was recorded in the developing countries.

The United States recorded a slight decrease compared to the previous year, but they still hold the second position, with 11,7%. In the classification of the producing countries Brazil and Russia are holding the next positions. In 2011, there were produced around 1,9 billions of hectolitres beer all over in the world. A quarter of this amount came back to China, which produced 490 million hectolitres, this is what shows the data of a report made by Barth – Haas Group.

The United States came second in the classification. Last year, the Americans produced 225 million hectolitres beer. According to the survey, towards the end of 2011 in the USA there were 1989 brewers, most of them representing small private breweries.

In Romania 17 thousands of hectolitres beer were produced last year, which ranks us on the tenth place in Europe, on an equality with France. It must be mentioned that the volume of beer production in Romania maintained at the same level as in 2010.

Romania held the 11th place in the beer production in 2011 in Europe as it can be seen in the following classification table:

TABLE I
BEER PRODUCTION IN 2011 IN EUROPE

No.	Country	Production (thousands hl)
1	Russia	98.140
2	Germany	95.545
3	Great Britain	45.701
4	Poland	37.850
5	Spain	33.600
6	Ukraine	30.510
7	Holland	23.600
8	Czech Republic	18.191
9	Belgium	18.150
10	France	17.100
11	Romania	17.100

The total volume of the beer production in Romania reached 17,1 million hl in 2011, it maintains almost at the same level as the previous year, and the sales of the members of Romania's Brewers Association reached a volume of 15,6 million hl. The total investments made by the members of the Association recorded 61 million Euro in 2011, increasing with 10 million Euro compared to 2010 according to the data published by Romania's Brewers Asssociation.

Source: http://www.forbes.ro/Piata-berii-se-mentine-la-volumul-de-anul-trecut_0_2110.html

The beer excises increased with 10% starting with the first of February 2013, according to the most recent changes of the Fiscal Code, and the impact study of the Public Finance Ministry /PFM/ estimates a price increase of 2%. The beer excises have not been raised for the last five years and the measure will add to the budget some extra 80 millions lei.

The representatives of Romania's Brewers Association (ABR) insist that a 10% increase of the beer excise will not reach its goal and its impact will be a negative one at the level of the revenues collected to the state budget. From the official data, it results that in 2011 the collection to the state budget only from the beer excise recorded a value of 59,27% from the amount of the value obtained for the whole category of excisable alcoholic products; meanwhile, the European average is of 31,26%.

Also, the excise collections for beer in 2012 were in amount of 620 millions lei as compared to 580 millions lei in 2011. The beer production in Romania reported at the European level represents 4,44% from the total beer production of 383 million hectolitres, the imports being situated at only 1,5% out of the total amount. At present, at a national level there are 20 breweries functioning and in the profile sector they generate either directly or indirectly 76.000 jobs whereas 98,4% of the beer consumed in Romania comes from the internal production. The first five brewers in Romania are:

- SAB-Miller with breweries in Timisoara, Buzau, Brasov.
- Heineken with breweries in Miercurea Ciuc, Târgu Mureş, Craiova and Constanţa.
- Molson Coors with the brewery from Ploiesti.
- Tuborg with the brewery from Pantelimon – Bucharest.
- SC Romaqua Group SA with the brewery from Sebes.

According to the modified Fiscal Code, the level of beer excise increases from 0,748 euro/ hl/ Plato degree. to 0,8228 euro/ hl / Plato degree. For the beer produced by the small brewers, the excise will increase from 0,43 euro/ hl/ Plato degree to 0, 473 euro/ hl/ Plato degree.

These rates of excise duty on beer and fermented beverages, others than beer and wine, must be correlated with the content of alcohol and the process of manufacture. Thus, for the beer / proportion of beer from the mixture with non-alcoholic beverages, for which the share of Plato degrees obtained from malt, malted grain and /or unmalted grain is less than 30%, there will be collected a supplimentary excise of 10 euro / hl of product.

Romania practises the minimum level of excise imposed at the level of the European Union, namely 0,748euro/hl/Plato°.

Source: http://www.bizlawyer.ro/stiri/juridice/accize le-la-bere-cresc-cu-10-de-la-1-februarie-preturile-s-ar-putea-majora-cu-2

II. GENERAL CONSIDERATIONS

Considerations to be taken into account when positioning a brewery

In order to position a new brewery there are a couple of factors that have to be taken into account and which

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

contribute to achieving investment success. There have to be made a marketing and a market study, a detailed survey in order to establish the capacity of production targeted or which, eventually, can be reached within stages of development. There must be very well set the type of beer we want to produce and the consumer segment we want to target. The technical level of the brewery must be selected and established in such a way that it might have a minimum impact on the environment according to the legislation in force with reference to the environment protection. Considering the fact that almost 90% of beer means water, we have to check with specialized studies and ensure that from the point of view of water all requirements have been met regarding the quantity and water quality necessary for beer production.

Secondly, for the location of the factory landscaped areas must be chosen , away from districts and living residential areas according to the legislation in force, the wastewater treatment plant must be connected to an emissary, the connections to utilities, such as electricity, natural gas, computer connections must be easily achieved, Connections should be provided to the public roads and railways transportation in order to realise at low cost the supply of raw materials and the sale of the finished product.

When choosing the location of the brewery there must also be considered the possibility to ensure the human resources necessary for the beer production being well known the fact that not all regions in the country have tradition and experience in brewing and the expenses to instruct and train beer specialists mean additional financial efforts for the companies; moreover, for the efficient organization of the production in a brewery there is a great need of renowned and experienced specialists in brewing.

The improvement of wort production processes. After establishing the criteria and the technological, technical and organizational solutions, the most important thing remains to begin the wort production.

For a continuous production, the supply chain activity must be coordinated in such a manner that, before having finished the wet tests, all raw materials, auxiliary materials to be already brought into the factory in sufficient quantities in order to start and continue the production in continuous flow. All these can be accomplished on conditon the consumption norms, the technological parameters are already established when signing the building contracts of the brewery.

In our case, I am introducing a standard, a wort fabrication guide where the size of the batches may vary between 200 – 800 hl, choosing the option of producing ”high gravity” wort, that is musts with a high fermentable sugar concentration of 14˚ Plato using raw material of 75% malt and 25% corn and using the wort fabrication line made up of: wet mill called ”Variomill”, malted and unmalted mash tun,lauter tun, wort kettle with internal wort boiler, hop dosing unit, hot trub separation having the possibility to dissipate the DMS out of the wort, plate heat exchanger for the wort cooling.

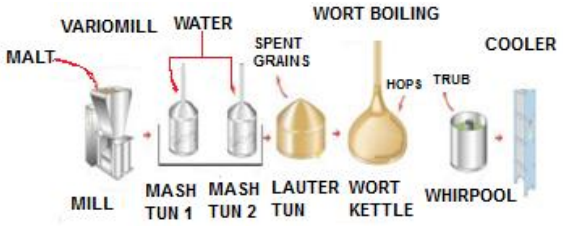

Fig. 1. Scheme of wort production line

For this manufacturing standard to be applicable with maximum efficiency, we must start from the point when by contract and by tracking parameters through consistent analysis we ensure the quality of the water and the raw materials of malt, corn, hop. The tables below present the technical specifications with the physico – chemical parametres that have to be obtained, required and respected for the raw water, the brewing water, for the malt and the corn used in brewing.

TABLE II
TECHNICAL SPECIFICATION FOR RAW WATER AND BREWING WATER

Parameter	*U M*	*RAW WATER*	*BREWING WATER*	
		Limits	Limits	Val. Det.
Ex. Organoleptic	-	Pleasant taste that satisfies the feeling of thirst, no smell, no colour	Pleasant taste that satisfies the feeling of thirst, no smell, no colour	
pH	-	6.5 - 9.5	6.5 - 7.5	
Turbidity	EBC	max. 1.25	max. 0.8	
Total durity	°G	≥ 5	-	
Remanent Alcalinity	°G	-	max. 5	
Nitrites	mg/dm3	max. 0.5	max. 0.1	
Nitrates	mg/dm3	max. 50	max. 30	
Iron	mg/dm3	max. 0.2	max. 0.2	
Content oxygen	µg/l	-	-	

TABLE III
TECHNICAL SPECIFICATION FOR LIGHTEN MALT

Parameters	U/M	Minimum	Maximum
Humidity	%		4.5
Fine extract , dry substance	%	81.7	
Extract as	%	78.0	
Diference of fine extract /	%		1.5
Saccharification time	min		15
Wort colour	EBC		4.0
Wort colour after boiling	EBC	5.0	7.0
Proteins	%		11.0
Soluble nitrogen	mg/100g	670	750
Kolbach Index	%	38.0	43.0
FAN	mg/ l	150.0	
Hartong VZ 45	%	37.0	
Viscosity	mPas	1.45	1.60
Friability	%	85	
WUG	%		2.0
β – Glucan (EBC Mash)	mg/ l		250
β – Glucan (65° Mash)			350
Ph		5.80	5.90
Diastatic power	WK	250	
DMSP	ppm		4.0
Grains > 2.5 mm	%	93	
Grains < 2.2 mm	%		1.0
Final fermentation degree	%	81	

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE IV
TECHNICAL SPECIFICATION CORN FOR BEER

Organoleptical examination:
Aspect; granular maize, without stable clusters
Colour: yellow - golden, specific to the corn it comes from
Pleasant smell and taste, characteristic, no modifications
Physico – chemical characteristics:
Humidity: max14.0%
Proteins: max 10.0%
Fats: max1.0%
Extract as: min.77.0%
Granulometry: >1,25 µm=max.5.0%
Granulation between 0.250- 1.0 µm=85.0%
< 0.125 µm=max 5.0%
Infesting: Negative
Metallic impurities: 3 mg/kg
The supplier guarantees that the raw material used is in accordance with all provisions of the Europen Community legislation. The raw material is not genetically modified.

The size of the wort batches is determined – if we use the equipment mentioned above – according to the following criteria:
- the type of milling used for the malt ;
- loading per m² of the Lauter tun ;
- the quantity and the cooled wort concentration per charge.

In order to make an adequate dimensioning of brew, I suggest the usage of table 5 - The recording and the raw material calculation for the brew.

TABLE V
RECORDING AND RAW MATERIAL CALCULATION FOR THE BREW

No. Crt.	Data	d	
1	No. Brew	x	
2	Type Malt/warehouse	A/n	
3	Total Malt, kg	mt	
4	Total Corn, kg	mlt	
5	Total Quantity raw material batch, kg	mt+ml=tmp	
6	Report water malt	3.1-3.2	
7	Total quantity water	(3.1-3.2)xtmp	
8	Total Quantity mash, hl	(3.1-3.2)tmp+0,7*xtmp	

Sources:

1. Berzescu, P., Dumitrescu, M., Hopulele, T., Kathrein, I., Stoicescu, Antoaneta, *Tehnologia berii şi a malţului*, Ceres Publishing House, Bucharest,1981, p. 120.

2. Kunze, W., *Technologie Brauer & Malzer,* Druk: Westkreuz-Druckerei Ahrens KG Berlin/Bonn, 2007, p. 129.

Where:

d – production date of the charge; *x*-Brew number; *A* – type of malt; *n* – number of silo; *mt* - total quantity of malt per charge; *mlt* - total quantity of corn per charge; *tmp* - total raw material per charge; *0,7* – conversion factor of malt in liters(1kg malţ= 0,7 litru).

The total mash quantity obtained per brew can be monitored according to figure where I present the monitoring of the total mash quantity for 29 brew of 500 hl with 14 ˚P.

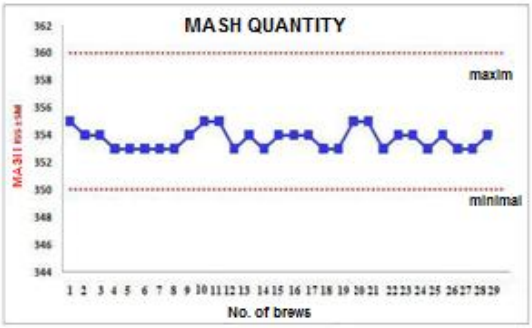

Fig. 2. Mash quantity per brew

Having the quantities of water, raw material and thus the total quantity of constant mash per brews, we have great chances that the qualitative parameters for wort to be constant all along the production process.

In case we notice a tendency of increasing or decreasing the quantity of the total mash for every two three consecutive brews, then we intervene and balance the situation by increasing or decreasing the quantity of water necessary to the milling.

The qualitative parameters of the filtered wort, which need to be respected and accomplished for a brew of 500 hl with 14˚P can be found in table VI - Qualitative parameters of filtered wort, total time taken , filter boiler.

TABLE VI
QUALITATIVE PARAMETERS OF FILTERED WORT, TOTAL FILTRATION TIME

No. Crt.	No. Batch	Val
1	Concentration of first wort , ˚P	14
2	Quantity first wort, hl	220
3	Quantity sparging water, hl	330
4	Quant. full kettle, hl	550
5	Extract full kettle, ˚P	13,3
6	Extract weak wort, ˚P	0,8
7	Quantity of weak wort, hl	37
8	Total filtration time, min	144

Where :

n.o = number; ˚P = Plato degrees; Quant. = quantity; hl = hectolitre; min = minute; val – value.

Keeping the mash quantity transfered, pumped into the lauter tun always constant, you will certainly obtain constant values for the first wort concentration as well, which will be 6-7 ˚P higher than the primitive extract desired in a full kettle. In this case it is recommended that the quantity of first wort should be filtered between 30 – 40 % out of the prescribed full kettle amount, and the quantity of the spargig water between 60 – 70 % out of the prescribed full kettle amount.

In order to be more efficient, it is very important that the total filtration time to be as much reduced as possible. This is why the old brewers from Germany (Bavaria) used to say that „the heart of the Brewhaus" section is the Lauter tun because on the efficiency of this equipment depends how long and how much wort will result hereafter from the process of beer manufacturing .

Below according to figure 3, I present to you the monitoring of the total filtration time for 29 batches with 550 hl of wort at full kettle, where the daily capacity is 10 charges / day.

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

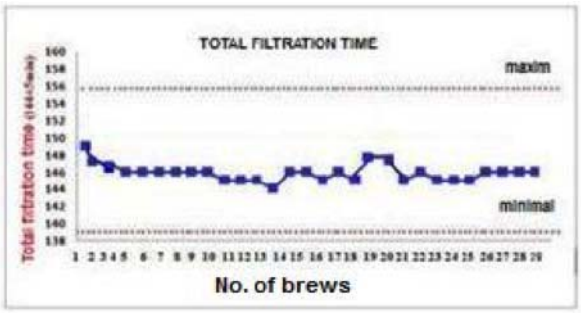

Fig. 3. Total filtration time

To fit the optimal time of total filtration time taken Lauter tun, the mash saccharification process must be directed impeccably and the pumping times of the saccharificated mash in the Lauter tun as well as the evacuation time of the spain grains out of the Lauter tun must be correlated in such a way that they don't influence negatively the total time of filtration.

At the same time, the quantities of first wort, the sparging water, the quantity of full kettle must be correlated with the concentration of first wort. If the concentration of first wort is lower , then the larger quantity of first wort is filtered and viceversa.

After the wort filtration is finished and the full amount and concentration of full kettle are being reached, follows the process of boiling wort with hop. For a good control – at this operation as well - of the parameters that compete to obtain a constant quantity and quality per brew, I suggest Table VII to be used: Boiling and cooling the wort.

TABLE VII
BOILING AND COOLING THE WORT

No.Crt.	No. Batch	
1	Total wort boiling time, min	
2	Hop quantity mgα-acizi/l	
3	Extract boiled wort °P	
4	Total trub quantity, hl	
5	Extract cooled must, °P	

Similarly to the production processes described above, in this phase of production it is also indicated to have a graphic monitoring at least for the variations of the extract concentration parameter and the cooled wort quantity per brews. An example of monitoring the extract concentration for the cooled wort is presented in figure 4 Extract cooled wort, and for the cooled wort quantity per brew is presented in figure 5.

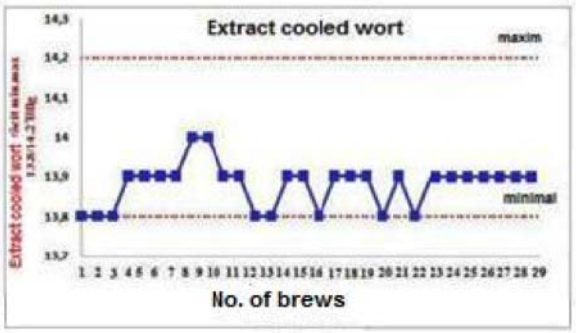

Fig. 4. Extract cooled wort

Fig. 5. Quantity cooled wort

With all necessary data available per brew, we can calculate the boiling yield per batch (formula Berzescu's book), the extract losses per brew, the malt and corn consumption per brew according to the formulas in Table VIII - Cooled wort quantity and Brewhaus yield.

TABLE VIII
COOLED WORT QUANTITY AND BREWHAUS YIELD

No.Crt.	No. Batch	
1	Cooled wort quantity, hl	cmr
2	Brewhaus yield, %	R=(CmrxCext/tmp)x100
3	Eextract loss, kg extract	ETI=Emt/sj+Eml/sj
4		Emt=mt/sj x malt extract
5		Eml=mlt/sj x corn extract
6		Pext.=ETI - ETR
7		ETR=Cmr x Emr
8	Malt consumption kg	Cmt=mt/cmr
9	Corn consumption, kg	Cml=mlt/cmr

Source: Narziss, L., *A sörgyártás*, Publishing House Mezőgazdasági Kiadó, Budapest,1981, p. 174.

Where:
Cmr = total cooled wort quantity per one brew, R = Brewhaus yield; Cext - extract content per 100 lt cooled wort at 20 ˚C; ETI = extract quantity used per brew,sj = brew; Emt = extract quantity resulted of malt used in one brew; Eml = extract quantity resulted of corn used in one brew; Pext = extract loss resulted per batch; ETR = Total extract resulted; Emr = extract quantity per cooled wort brew.

The necessary values for malt and corn extracts can be taken from the analysis bulletin provided by the supplier, an own laboratory or an independent laboratory accepted by both parts depending on the conditions established in the contract with the raw material supplier.

According to the results obtained after thorough analysis, there are set at the brewery level the measures to be taken in order to improve the activity of wort production.

III. CONCLUSIONS

By the way the processes of wort manufacturing are being presented in this paper, it can be considered that this paper is a production guide for making wort and it is based on the experience of wort manufacturing for more than 27 years.

With the help of this paper, the processes of wort manufacturing can be directed so that important parameters of wort quantity and quality be always constant and respect the predetermined deviation margins.

Working by the model presented , there can be made separately a graphic monitoring of the processes of wort manufacture , which allows us a more thorough analysis of the manufacturing processes, after which we can establish

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

the measures to be taken eventually in order to improve the efficiency of the wort manufacturing processes , consequently we can improve the Brewhaus yield and we can reduce the percentage of extract losses all along the wort manufacturing processes.

To put it more simply, there can be established the norms of raw material consumption wort/ hectoliter produced which is of great help in establishing the necessary raw material quantity for the production per week, per month, per year.

REFERENCES

[1] Begea, M., Stefan-Biris, F., Stroia, I., *Utilaje pentru industria maltului si al berii*, Editura Cison, 1998.
[2] Berzescu, P., Dumitrescu, M., Hopulele, T., Kathrein, I., Stoicescu, Antoaneta, *Tehnologia berii şi a malţului*, Editura Ceres, Bucuresti, 1981.
[3] Kunze, W., *Technologie Brauer & Malzer,* Druk: Westkreuz-Druckerei Ahrens KG Berlin/Bonn, 2007.
[4] Narziss, L., *A sörgyártás*, Editura Mezőgazdasági Kiadó, Budapest, 1981.
[5] Schmidt, H., *Katechismus der Brauerei-Praxis*, Nürnberg, 1989.

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)