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Colour analysing of IPA brewing phases, including daily measuring of the fermentation process

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Original article

Abstract

Over the last decade, the brewing revolution has shown a new face to brewing. Besides the large-scale production, small-scale, artisanal hand crafted, and home breweries have also become important and relevant. This change has forced large-scale companies to change their usual methods and brew other types of recipes as well.

One of the most popular ALE-type beers is the Indian Pale Ale (IPA), which gives beer a fruity-citrus flavour due to its hop content. It is especially popular with novice brewers as it has no enormous machine requirements compared to LAGER-type beers.

In the study, we made our already known and popular recipe, a New England IPA, in a 30-litre brewing pot. This type requires only one type of malt; however, we added barley flakes, oat flakes, and wheat flakes to enhance the flavour. Hops are very dominant in the taste of this type of beer, five of which were used during brewing and later at 'dry hopping' during fermentation.

Sampling was performed every minute during mashing, brewing, hopping, cooling, and yeasting with a calibrated NIX-type measuring device with repetition to avoid measurement errors. During the fermentation stage, the colour change was observed by daily sampling. The study aims to separate the stages of brewing by colour and identify the stages of the already known biological and chemical activities by colour.

This study is the first part of a more extended series of experiments where we will perform similar experiments on several types of beer (LAGER, STOUT, APA, WHEAT, RED, etc.). We would also like to know about the possible effect of carbonisation on colour, the possible effect of storage in a bottle on colour, and possible deviations from a similar decoction.

Keywords

- brewing
- color analysiation
- IPA
- wort
- color measuring

Authors contributions

A – Conceptualization
B – Methodology
C – Formal analysis
D – Software
E – Investigation
F – Data duration
G – Visualization
H – Writing – original draft preperation
I – Writing, reviewing & editing
J – Project administration
K – Funding acquisition

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Conflict of interest

None declared.

Introduction

Malting, mashing, brewing, fermentation, and bottling are usually mentioned among the beer brewing operational steps. All brew phases are essential, including mashing, when the grinded malt is mixed with water and slowly heated up, boiling when biological activation is eliminated, and hops (or part of the hops) are added, the cooling down or chilling, when particles are settling down [1–2]. The purpose of brew-mashing is that the valuable substances, proteins and still in soluble phase existing starch shall be dissolved to the greatest possible extent and be transformed into sugar. Mashing in the major breweries is run mainly by the decoction method. The characteristic of this decoction procedure is that 1/3 portion of the mash from the mash tun is led into a brewing kettle, which is gradually boiled and then pumped back into the mash tun to mix it up again with the rest of the mash. This step is repeated twice or three times, thus reaching the final temperature of 62–79°C of mashing. During microbrewing or home breweries, the infusion method is more commonly used; here, the entire content of the mash tun is gradually heated up to the desired temperature, applying necessary, multiple pause periods. While this study focuses on microbrewing, we will focus on this infusion method. According to the infusion method, after reaching the desired mashing temperature, the mash is stirred until the transformation of starch into fermentable sugars terminates.

The spreading and popularity of micro-breweries vary country by country and era by era, but from 2010 most countries (where there are no anti-alcohol laws) report a definitive increase. Even in a micro-brewing technology, brewing the beer starts with grinding the barley or malt (Figure 1.). Grinding the malt is a process executed among cylinders which is of vital importance from the perspective of chemical-biological transformations executed while mashing, qualitative composition and extraction of wort furthermore yield [3–4]. Grinding the malt is milling, executed between rollers, which is vital from the aspects of chemical-biological transformations during mashing.

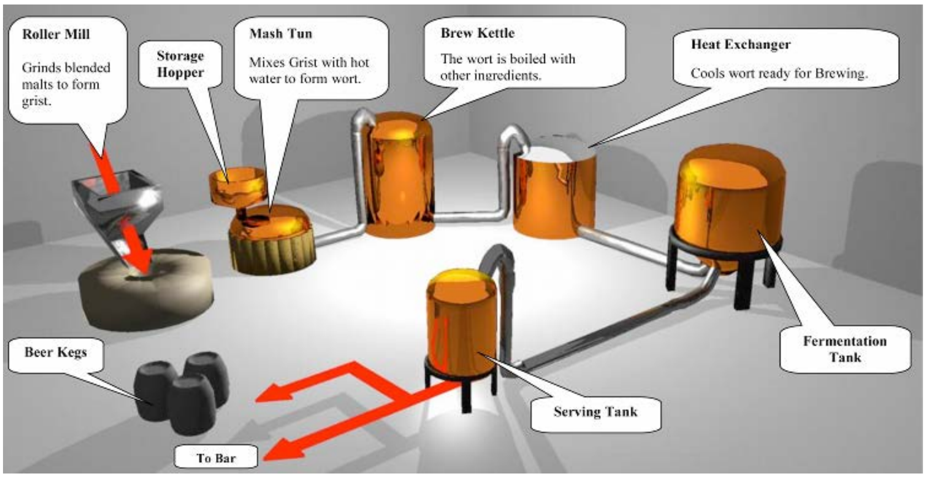

Figure 1. Brewing technology

Checking the malt grist in small-scale production-routine takes place by visual control, but using the sieves series makes it possible to acquire quantified evaluation. With the sieve series, the structure of the grist can be established, the distribution of grain size is easy to depict in graphs, and average grain size, which is characteristic of the grist, might also be determined [5–11]. The further technological step is the mashing mentioned above, during which the grist of malt is mixed with water during slow heating. The aim of the process is that valuable substances in the grist of malt, like proteins, still soluble starch, shall be dissolved at an as high ratio as possible and be transformed into sugar. In smaller facilities and home breweries, the content of the mashing tank is gradually heated to the wished 62–75°C temperature, applying more pauses as and when necessary. Mashing is accomplished with starch transforming into sugar which can be checked by using an iodine test [13–15]. For quick determination, the extract produced during the mashing is carried out by using Balling-grade [°B] or Brix-grade [°Bx] measurement unit in laboratories; the extract- and dry substance content of wort might be determined by analytical means as well [13,16].

Methods of brewing and later hop-boiling (electrical, gas-operated, etc.) determine beer brewing from economic and environmental aspects. Lately, the technologies are deemed as environmental-conscious where energy consumption is reduced, water consumption is reduced, or the amount of waste is reduced. Restructuring the technologies and taking the possibilities into consideration may result in solutions that can reduce the energy demand of the given production process by recycling a specific waste/byproduct produced during a technology phase [17]. Besides that, the micro-scale practice uses electric energy for grinding, circulating the liquids and cooling, but in many cases mashing and hop boiling is also carried out by using electric heating elements. From this perspective, it is worth examining the grinding process from the beer production technological steps. While the iodine test is accurate and could be replaced by Balling-grade [°B] or Brix-grade [°Bx] measurement unit, those methods need sampling, calibration and automatisation; mechanisation is almost impossible. Colour chart comparison is a great alternative when the recipe is followed. Sampling is more accessible, needs fewer samples, and does not need any chemicals.

Colour was a subjective perception and interpretation of what an individual sees and observes till the era of digitalization. However, defining what 'colour' really means, as information containing, is challenging [18–19]. Colour is a visual sensation attribute, and the color appearance of an object can be determined by three factors: the light source, object and visual system. An object appears to have colours because it absorbs certain optical wavelengths coming from the light source and reflects certain wavelengths [20].

However, defining a colour is still challenging, typically, colour is expressed using three dimensions which include, hue, chroma, and lightness [21]. Hue is how an individual recognizes an object's color (e.g., blue, yellow, green, or red). Chroma shows how close the color is to gray or a pure hue, while lightness represents the comparison of the color as light or dark. However, those three dimensions are insufficient to fully specify color appearance. In fact, a complete specification of color appearance requires five perceptual dimensions: hue, chroma, colorfulness, lightness, and brightness [22].

Colour representation as information holding became popular in many industrial, environmental and agricultural acts. According to Hasnu Hadi et al. [23], colour measuring is a decent way to characterize amber coloured liquids, such as crude oil, palm oil, various seed oils, and even maple syrup but it is already used to detect brewer's yeast [24].

This study aims to measure the colour and colour-saturation continiously of the wort from the start of the mashing till the consumption. At the same time, Brix-grade [°Bx] and temperature [°C] is by-measured as a reference by a calibrated refractometer (calibration was performed with distilled water a few minutes before the measuring campaign).

Materials and methods

Process of brewing beer

As the first step of this long-term, multi-stage measurement campaign, we decided to go for a brew with simple heat steps while colour change is predictable. For this reason, the research went for New England Indian Pale Ale (NEIPA) with dry hopping. NEIPA has a hazy, cloudy beer appearance; the saturation is higher than a settled, clear lager; NEIPA is an excellent initial measuring ale-liquid.

The yield was calculated for 26 litres; we mashed 4.5 g of ALE type barley malt, 0.7 kg of barley flake, 0.7 g of oat flake, 0.4 kg of wheat flake, and 1 litre of rice hulls. Rice hulls support the settling during chilling; as we know, it does not add flavour, odour, or colour.

While water dramatically impacts the taste of beers and ales, we would like to repeat the measuring campaign, so we used distilled water to avoid varying the water. The pot was automatised for heat steps, so there was no latency during mashing. The process steps are demonstrated in Table 1., it is a well recommended guidline while brewing NEIPA ale. At reaching 53°C, the malt mixture (barley malt, barley flake, oat flake, wheat flake and rice hull) was loaded into the pot, and the water was heated further to 67°C. This temperature activates equally the beta and the alpha-amylase for hydrolysis starch. We let the wort rest at 67°C for 60 minutes. After we eliminated the biological activity (increasing the temperature to 78°C for 15 minutes), we started to rinse the removed malt mixture with heated distilled water (90°C), and room temperature distilled water (22°C) and let the malt mixture drips off.

The temperature was increased to boiling (100°C) for 60 minutes. Evaporating water was replaced by distilled hot water, and we kept the Brix grade at 14°Bx. At 45 minutes, the first portion of hops was added: 50 g of Amarillo pellets were placed into the liquid, using spider-hop (instead of hop-sack) for better dissolving. When 60 minutes of boiling had ended, we placed the next portion of hops, and it was in the wort till the transfer into the fermenter. The second mixture of the hops (all pellets) was the following: Citra 30 g, Galaxy 30 g, Mosaic 30 g, Villamette 20 g. NEIPA always brews and includes a high amount of hops.

Before we eliminated biological activity, we gathered 500 ml of the wort into a 2-litre flask (sterilised alembic), and after cooling it down to room temperature (22°C), we created a starter liquid with the yeast. We dissolved 10 g of Brew Ar Tech New England yeast for fermentation. While 10 g of yeast is only enough for 20–25 litres of wort, this starter liquid is decent for 30 litres of wort to ferment.

Before we transferred the wort into the fermenter cask, we let it settle for 60 minutes, so 'floaties' (small chunks of coagulated protein that have fallen out of the solution of the liquid beer) were settled. This part is unnecessary, but the ale appearance is better when applied.

Table 1. Table of steps of brewing processes

Item	Process	Temperature	Elapsed time	Miscellaneous
1.	Pre-heating / malt resting	53°C	15 minutes	Adding malt to water
2.	Mashing	67°C	60 minutes	Malt extraction
3.	Biological elimination	78°C	15 minutes	
4.	Rinsing	—	20 minutes	alternate rinsing water
5.	Brewing	100°C	60 minutes	adding hops
6.	Cooling / Whirlpooling	22°C	—	reaching low temperature
7.	Yeasting	22°C	—	adding yeast
8.	Fermentation I	22°C	3 days	main fermentation
9.	Fermentation II	22°C	11 days	secondary fermentation, dry hopping
10.	Bottling / Carbonisation	22°C	14 days	adding inert sugar

Fermentation

After the transfer to the fermenter cask, we mixed in the starter yeast mixture, closed the fermenter, and shook the fermenter for 30 seconds, to increase the DO (dissolved oxygen) level for better fermentation. The fermenter was installed in a room at a constant 20°C.

After three days, the fermenting wort received the first dry hop dose (all pellets): Citra 60 g, Galaxy 30 g, Mosaic 30 g, Villamatte 10 g. This time sterilised hop sack was applied. After four days (7 days after fermentation started), the wort received the second dose of dry hop (pellets): Azzacca 50 g.

After seven more days, the wort was ready for bottling. Avoiding the oxygen dissolving, we used a long-neck loader in the bottles, 5 g of sugar were added to each bottle (for carbonisation), and then all bottles (78 bottles – around 25.74 litres) were capped, carbonisation process began.

Measuring the colour

For measuring, we used a NIX COLOR PRO handheld measurer with its own calibrated white background. We always took a 10 ml sample of the wort and sampled it with an eyedropper.

During the mashing, rinsing, boiling, warm hoping, cooling and settling: samples were taken every 60 seconds. During fermentation, dry hopping and carbonisation samples were taken daily. We repeated every measure three times (individual drops from the 10 ml shook sample) and calculated the average, so every minute shows average data. If a scatter of a sample was over 5%, we repeated the measuring with a new drop (it happened only two times).

NIX COLOR PRO uses its own light and sensor system, so external light sources were not influencing the measuring. Many colour profiles were recorded, but in this study, we focused on RGB, which is the easiest way to follow.

We sampled the wort (and the ale) 267 times, according to Table 2.

Table 2. Table of the number of samples

Process name	Collected samples
Increasing temperature	15
Mashing	61
Eliminate biological activity and rinsing	26
Boiling	62
Cooling	18
Settling	55
Fermentation and dry hopping	15
Carbonisation period	14
Finished ale	1
SUM	**267**

Heat makes no difference in the colour measuring, as our previous application has proven, so sampling heat was not considered.

Evaluation of measurement data

In Excel, we collected all measured data and made a comparison. NIX COLOR PRO software calculates in HEX-decimal code, but it calculates red, green, and blue (RGB) channels separately (0–255), so no further data exchange was applied.

Colour changing could not be described as linear or logarithmical (because of the significant scattering). Visual appearance was not available by using linear or logarithmical gradients. Applying 60 or more colour bars is hardly interpretable, so while the chart data is accurate, the appeared colours have only representative purpose of the study: from starting point to finish point gradient.

Results and discussion

Figure 2 presents the colour changes during the brewing process of the subjected NEIPA brew with a time quantised colour visualisation layered in the background. However the last two-phase were sampled daily instead of per minute, it is a bit confusing, but it makes no sense to quantise them in real-time because the first six-phase took less than five hours, but the

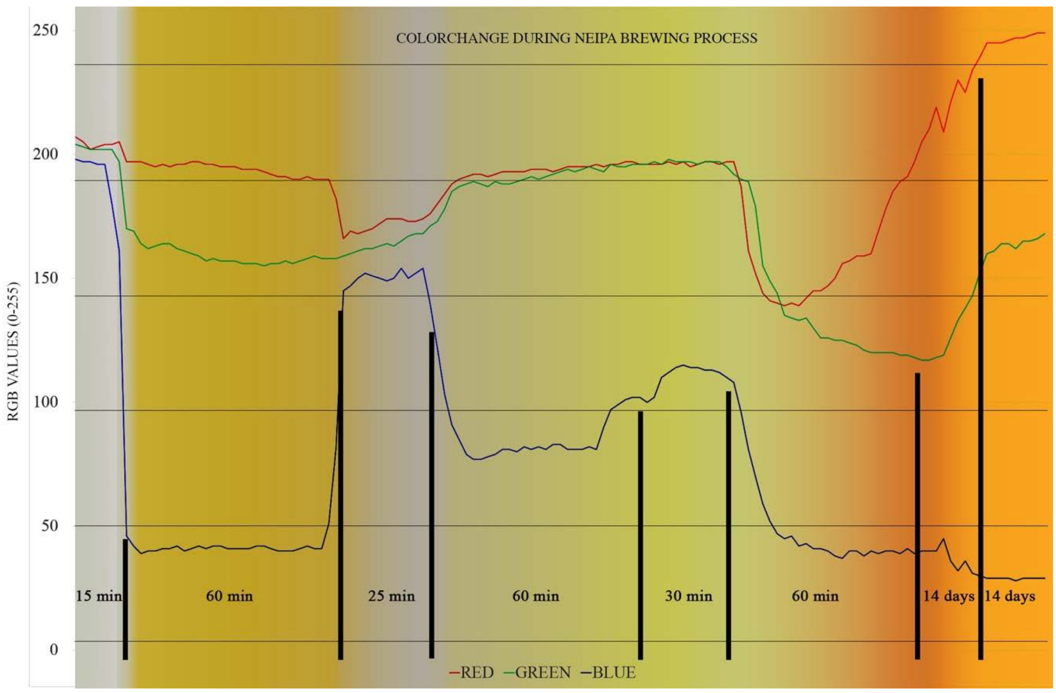

Figure 2. Time quantised colour visualisation on the RGB chart, with time quantisation labelling

last two phases took four weeks. Vertical values are set between 0 and 255, usually at RGB values. The whole chart is presented with indicating technological steps signs; however, all phases are easily separable based on the colors also. On RGB mixing RED channel mixed with GREEN channel gives the yellow colour, and while IPA style Ale's are usually close to yellow, as Figure 2 demonstrates: RED and GREEN channels always reach higher values, and usually RED channel reach even higher, so the tone transfer into orange-like colour.

Figure 2 presents, however, three increases in the BLUE channel. The first increase is when biological activity has been eliminated, but maybe this is only the massive amount of foam that distorts the values; the colour is closer to white-grey with a hint of yellow. The second was at the end of the boiling phase when hops were added to the wort. Even though hop pellets are green, the GREEN channel was not increased significantly, while the BLUE channel shows increasing. The third more negligible phenomenon was two minor spikes in the fermentation phase when dry hopping was done, but it was just two little spikes.

Figure 2 demonstrates that during the heat transfer phases (heating, mashing, boiling) RED channel stagnates, and the scattering is under 10%. The rinsing phase presents a smaller drop, but the foaming can cause it. Despite a massive drop at the settling phase, it is increasing rapidly, mainly because the GREEN channel decreases even more. The settling of floaties can explain this phenomenon and many hops and malt particles. On the RED channel, two harmful spikes are detectable at the time when the dry-hopping process happens.

In Figure 2, we can see a white-grey area in the third phase, and this is the phase when the RED channel drops and the BLUE channel increases simultaneously. As it was mentioned above, this phenomenon is may caused by foaming. An almost reddish colour is detectable in the background, but it is a short period in time; this is the end of the settling, when floaties were settling down, making a decrease on the GREEN channel, which was increasing steadily during the fermentation and dry-hopping process.

Conclusion and discussion

This study is the first step in a long and intensive measuring campaign. After understanding the colour changing, it is recommended to repeat the brewing processes with the same measuring method and search for physical or chemical parameters and presumably correlation between them.

However, temperature and Brix grade was recorded; this study focuses only on the colours alone, as a flagship to this long project.

The study demonstrates that variation of the colours is detectable, and a gradient could describe every process. These colour gradients are easily separable, as are the brewing process phases.

According to Caro [25], colour can be a relevant indicator, thus this technology is new but reliable, which supports this study. Barth et al. [26] used LED lighting instead of spectrophotometers, which indicates the need for an easy-usable colour measuring device. Our study supports this requirement.

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