MONASH BREWLAB

PERFORMANCE ANALYSIS AND COMPARISON BETWEEN TWO YEAST STRAINS: US-05 AND CN-36

October 2019

Experiment and report by Monash BrewLab
Report elaborated for Keg King Australia

MONASH BREWLAB

EXECUTIVE SUMMARY.

Yeast, a single-cell organism and the simplest form of fungi life, is responsible for the fermentation process in beer. Yeast essentially takes in simple sugars like glucose and maltose, and produces carbon dioxide and alcohol. Because of the temperature differential, each yeast strain produces vastly different flavour and aroma characteristics that, in turn, create the different beer styles. Yeast, in combination with different fermentation processes and ingredients, can also contribute with various flavour characteristics to the beer.

In this experiment two similar yeast strains, US-05 and CN-36 are compared against each other. In order to eliminate any differences in the brewing process, two identical fresh wort kits were used to carry to experiment, each one with different yeast strain pitched dry. Additionally, all the fermentation equipment as well as the fermentation process conditions were kept identical for both set ups to further minimise differences in methodology.

In order to determine the differences between the two yeast strains, factors such as rate of fermentation, apparent attenuation and flocculation were studied for both the products. CN-36 was found to be more vigorous and faster fermenting than US-05 despite having a later start to fermentation. It flocculated more efficiently than US-05 leading in higher clarity and clumping. CN-36 also appears to have a wider range of temperature for yeast activity, having achieved more attenuation at secondary fermentation with low temperatures. However, US-05 still achieved a higher percentage of apparent attenuation.

In addition to comparing the fermentation process, the effect of each yeast strain on the finished product quality was also analysed through a triangle test and a blind sensory evaluation. The triangle test aided in gauging if there was a considerable difference between the two final products, while the sensory evaluation helped to analyse the appearance, body, aroma, and flavour profile of the two products.

The results of the triangle test indicate that there is a clear difference perceived between the two products. The results of the sensory evaluation showed that there were clear flaws in both beers, mainly acetaldehyde, diacetyl, and oxidation. These are attributed to possible leaks during the fermentation process. However, the beer brewed with CN-36 appears to have a better ability to reabsorb these by-products, producing a better quality beer at high oxidation conditions.

In conclusion, according to the results obtained through this single experiment, CN-36 proved to be a more universal, cleaner and faster fermenting yeast strain. However, because of the particular conditions of this sample and to strengthen statistical accuracy, more experiments of this nature are encouraged to be undertaken for a variety of different styles.

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1 INTRODUCTION.

US-05, *Saccharomyces cerevisiae*, is an American ale yeast that produces well-balanced beers with low diacetyl and a clean, crisp end palate [1]. It generally forms a firm head and has a very good ability to stay in suspension during fermentation. The dry weight of US-05 yeast is 94% - 96.5%. It contains more than $6x10^9$ cfu/g of living yeast cells and less than one cfu/ml of wild yeast cells. The expected characteristics of US-05 yeast are listed below:

1. Flocculation: Medium
2. Attenuation: 77% to 81%
3. Sedimentation: Medium
4. Esters: Low (less than 40 ppm)
5. Alcohol Tolerance: 9% to 11%

CN-36 is a yeast strain used to produce varieties of common ale styles. It is said to lead a vigorous fermentation, high attenuation and high flocculation [2]. It triggers a quick start to fermentation, reaching final gravity after 4 days at 18°C. It may present a mild ester aroma. Although CN-36 is the same yeast species as US-05, *Saccharomyces cerevisiae,* its subtype or strain differs, thus it is expected to have subtle differences. The dry weight of CN-36 yeast is higher than 93%. It contains more than $8x10^9$ cfu/g of living yeast cells and less than $1x10^3$ cfu/g of wild yeast cells. The expected characteristics of CN-36 yeast are listed below:

1. Flocculation: High
2. Attenuation: 65% to 80%
3. Sedimentation: Medium
4. Esters: Low
5. Alcohol Tolerance: more than 6%

Summer Ale wort kits provided by Keg King were used to determine whether the two yeast strains are comparable in terms of performance. The objective of the experiment was to analyse the performance of US-05 and CN-36 yeasts during fermentation and ascertain the sensory differences as final product.

Note: Yeasts were dry pitched to be able to properly compare the performance of the yeast strains and reduce variability due to hydration or starter cultures.

2 AIM.

Analyse the performance of US-05 yeast and CN-36 yeast side by side during fermentation. After obtaining the final product, conduct a sensory evaluation and triangle test to determine if the beer presents different sensory characteristics.

3 MATERIALS AND METHOD.

3.1 MATERIALS

16.5 L Summer Ale wort kit, Dry yeast: US-05 and CN-36 provided by Keg King

Tilt hydrometers, Fermentasaurus, temperature controllers and fridge provided by Monash Brew Lab

3.2 METHODS

Temperature and Gravity of beer throughout fermentation were monitored using tilt hydrometers.

Apparent attenuation is calculated by using the following formula, obtained from [3]:

$$\%\ Attenuation = (OG - FG)/(OG - 1) * 100\% \quad [A]$$

Flocculation was qualitatively determined. Images were taken twice per day until the end of fermentation. It was noted as low (no sediment), medium (some sediment but creamy) and high (sediment and clumpy).

Sensory evaluation, triangle test hypothesis was determined using the following formula [B]:

$$X^2 = \Sigma\ (|O-E|)^2/E \quad [B]$$

4 FERMENTATION RESULTS AND ANALYSIS.

4.1 GRAVITY OF BEER

The fermentation of the pitched wort was monitored for 6 days until the gravity showed no significant change. Figure 1.1 indicates that the gravity of the wort pitched with CN-36 (CN-36 beer) decreased at a higher rate during primary fermentation (days 1 to 3), as compared to wort pitched with US-05 yeast (US-05 beer). The gravity of CN-36 beer reached a constant value before US-05 beer, which suggests a higher rate of fermentation by CN-36. Nevertheless, the final gravity of US-05 beer is 1.009, slightly lower than CN-36 beer (1.010).

The gravity of US-05 beer remained constant at 1.009 since completion of primary fermentation and throughout secondary fermentation. The gravity of CN-36 beer, however, changed from 1.012 (at the end of primary fermentation) to 1.010 by the end of secondary fermentation. CN-36 and US-05 beers achieved final gravity of 1.010 and 1.009, respectively, and were then transferred to kegs.

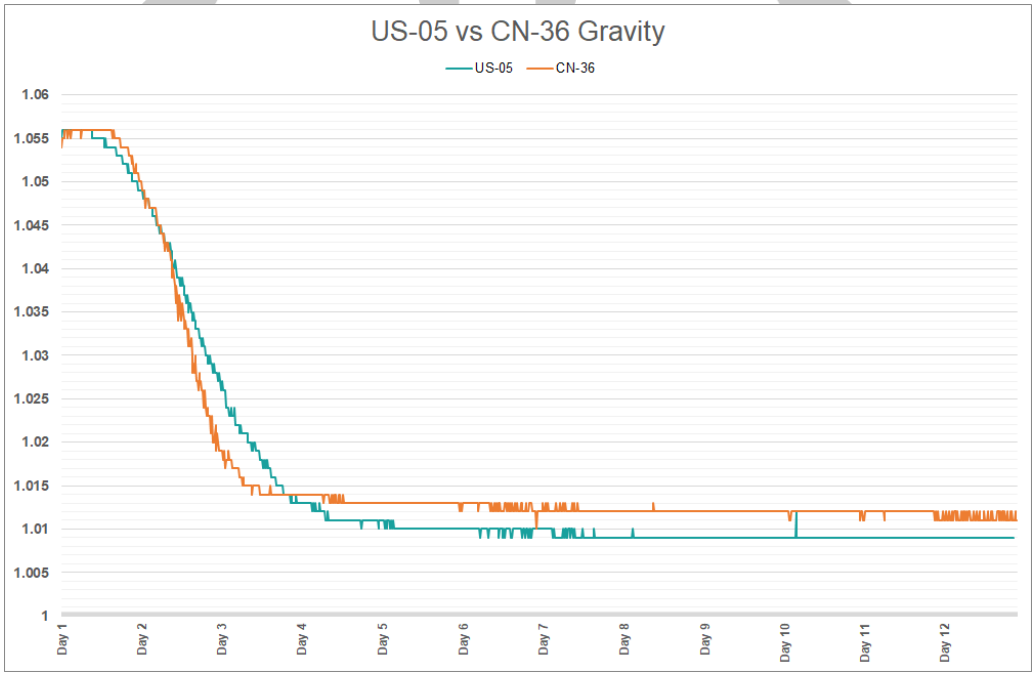


Figure 1.1: Graph of gravity versus time

4.2 TEMPERATURE OF FERMENTATION

The temperature of the wort throughout the fermentation process is shown in Figure 1.2. After allowing the wort to reach 20°C, the yeast was pitched. As the figure indicates, the fermentation occurred with minor fluctuations: the slight variations on temperature are assumed insignificant to the actual fermentation process in the Fermentasauri.

After completion of primary fermentation, the temperatures for both fermentors were decreased 1°C each day for secondary fermentation, until the temperature reached 3°C. The primary and secondary fermentation processes took a total of 24 days to complete.

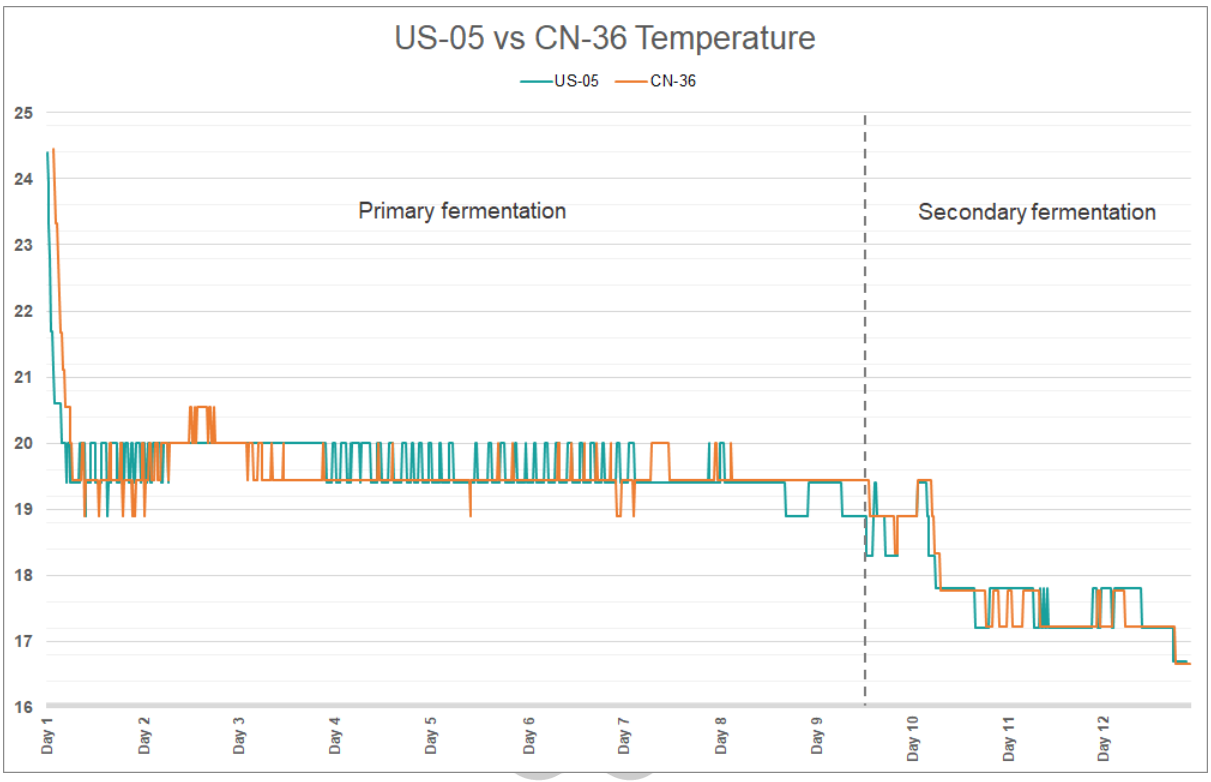


Figure 1.2: Graph of temperature versus time, with primary fermentation and secondary fermentation segments labelled.

4.3 Apparent Attenuation

The apparent attenuation was calculated during the fermentation process using formula [A].

Obtained data show that US-05 beer has higher percentage of apparent attenuation, as the final gravity is lower than CN-36, which indicates a higher conversion rate of sugars into alcohol and carbon dioxide. On the other hand, CN-36 had a steeper increasing trend in attenuation before reaching constant gravity, which suggest it took a shorter time to convert the sugars and hence the fermentation process was completed in a shorter period of time, specifically 60 hours vs 80 hours.

Although CN-36 had a faster fermentation, it took approximately 14 hours before the attenuation started to increase, while for US-05, the increase was noticeable only after 8 hours since the fermentation process was started. At the end of primary fermentation the apparent attenuation for CN-36 and US-05 beer was 79% and 84%, respectively. This may indicate that, regardless of the increased rate to convert sugars into ethanol, CN-36 is less efficient than US-05.

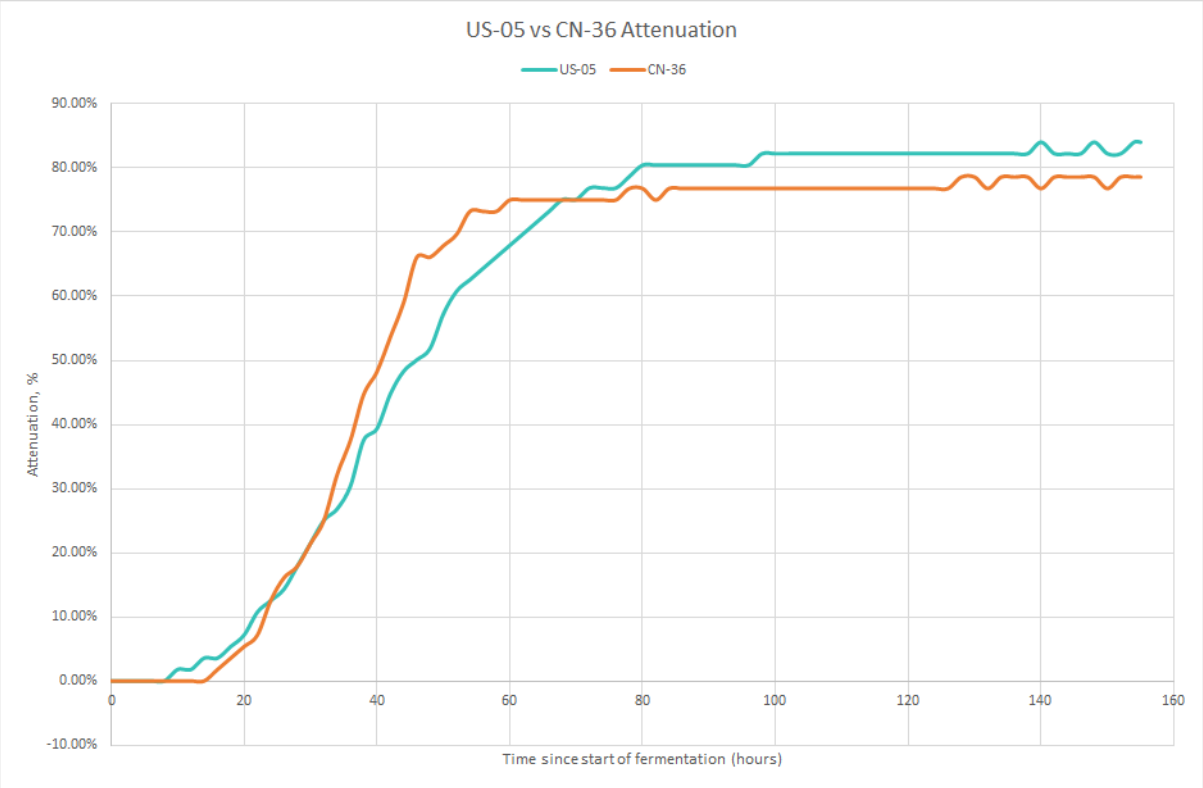


Figure 1.3: Graph of percentage apparent attenuation versus time

4.4 FLOCCULATION

The flocculation quality was monitored for the first 6 days of fermentation. The height of flocculated yeast was recorded two times a day, in the morning and evening, with at least 7-hour intervals. Table 1.4 shows the recorded data of flocculation quality.

Table 1.4: Flocculation quality results

Day 0 (14/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
			
Soluble yeast. No visible sediment.	Soluble but clumpy yeast. No visible sediment	Considerable sediment present after 8 hours. Sediment was observed as in clusters. Smaller clusters were suspended	Considerable heterogeneous sediment present after 8 hours. Smaller clusters were suspended. Yeast colour appears to be darker than US-05

Day 1 (15/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
			
Floc. particles finer than with CN-36 floc, particles seemed more dispersed in wort - made it look a bit cloudy	Tiny sand-like floc. particles floating to about halfway up FRMS, light brown - clay coloured, amber gold wort, about 5mm of foam on top, bulge forming in middle	Tiny sand-sized floc. particle, dark golden brown colour, few shades darker than CN-36 floc, the movement of yeast in the keg is less aggressive than CN-36, dark amber-coloured wort in keg, amount of foam on top is about one-finger, less than CN-36.	Tiny floc. particles with some bigger lumps clearly seen, light brown, brighter than US-05 floc. The colour of floc and wort has obvious difference. The movement of yeast is aggressive. Wort colour is close to light amber brown, foam is more than a palm-wide.

Day 2 (16/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
			
Tiny lumps of floc, brown colour floc, much darker than CN-36. Some sediment can be seen at the surface of FRMS. Less aggressive than CN-36. Wort colour has not much difference comparing to yesterday. Little foam, less than a finger.	Floc settled to bottom, layer-like instead of lumps, colour of floc turns to off-white, height decreased slightly, wort turned cloudy and golden colour, a lot of yeast sediment can be seen on the surface of FRMS. Foam of more than a palm, wort colour is cloudy golden.	Recovery bottle contains few sediments. Fermenting wort looks cloudy and homogeneous	Recovery bottle appears to be almost full. Active fermentation is visible and clumps of yeast are observed in the fermenting wort

Day 3 (17/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
		No measurements were carried out this day (Saturday night)	
Floc is not obvious in the recovery bottle, but sediment can be seen in FRMS. The colour of floc and wort is hard to distinguish. Colour of wort is brighter than previous. Wort is still cloudy and amber brown-coloured.	The collection bottle is filled, obvious sediment on the bottom of FRMS. Colour of floc is close to creamy beige. The wort turns clearer at the top and colour turns lighter to light brown. The amount of foam is reduced to very little, concentrated in the middle.		

Day 4 (18/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
			
Air bubbling up through flocculated yeast. Smell is quite yeasty and earthy. Light brown in colour	No massive difference to US05, except less smell. Still light brown, air bubbles bubbling through flocculated yeast.	A lot more flocculated yeast. Darker brown in colour	Light brown, big air bubbles, less flocculated yeast
Day 5 (19/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
			
Recovery bottle is full, 2 layers of floc	Recovery bottle is full, bigger lumps	Fermenting wort appears to be	Fermenting wort continues to have

seen in FRMS, floc colour is light brown, off-white floc layer at the bottom of FRMS, colour of wort is amber/brown, cloudy wort, very little foam	settling on the side of FRMS, settling movement of lumps can be observed, floc colour is brighter than US-05, more air bubbles and movement of air bubbles are seen. Wort colour is golden brown, top layer of wort is clear, very little-no foam.	homogenous. Recovery bottle was filled with creamy yeast sediment. On top of the bottle appears to be 2 layers of sediment of different colour and density	some suspended clusters. Recovery bottle was filled with creamy, bubbly yeast sediment. On top of the bottle, sediment continues to accumulate.
Day 6 (20/8/2019)			
Morning		Evening	
US-05	CN-36	US-05	CN-36
		No measurements, preparing for secondary fermentation	
Recovery bottle is full, 2 layers of floc seen in FRMS, floc colour is brown, off-white floc layer at the bottom of FRMS, off-white layer is thicker than yesterday. Colour of wort is amber/brown, still cloudy wort, but towards top part of wort, clearer wort can be seen, very little foam	Recovery bottle is full, bigger lumps settling on the side of FRMS, most of the lumps had settled, but a few lumps still settling, floc colour is brighter than US-05, layer of settled lump is in light brown. Wort colour is golden brown, top layer of wort is clear, very little-no foam.		

4.5 SECONDARY FERMENTATION

As mentioned, secondary fermentation was carried out for both beers by reducing the 1°C per day until the final temperature was 3°C.

Apparent attenuation was also monitored during secondary fermentation. Figure 1.5 shows how CN-36 still increased apparent attenuation at lower temperatures from 1.012 to 1.010. Therefore, the apparent attenuation of CN-36 beer increased from 78.57% to 81.48% after completion of maturation process. The attenuation of US-05 beer (83.93% after completion of primary fermentation) showed no changes over this stage.

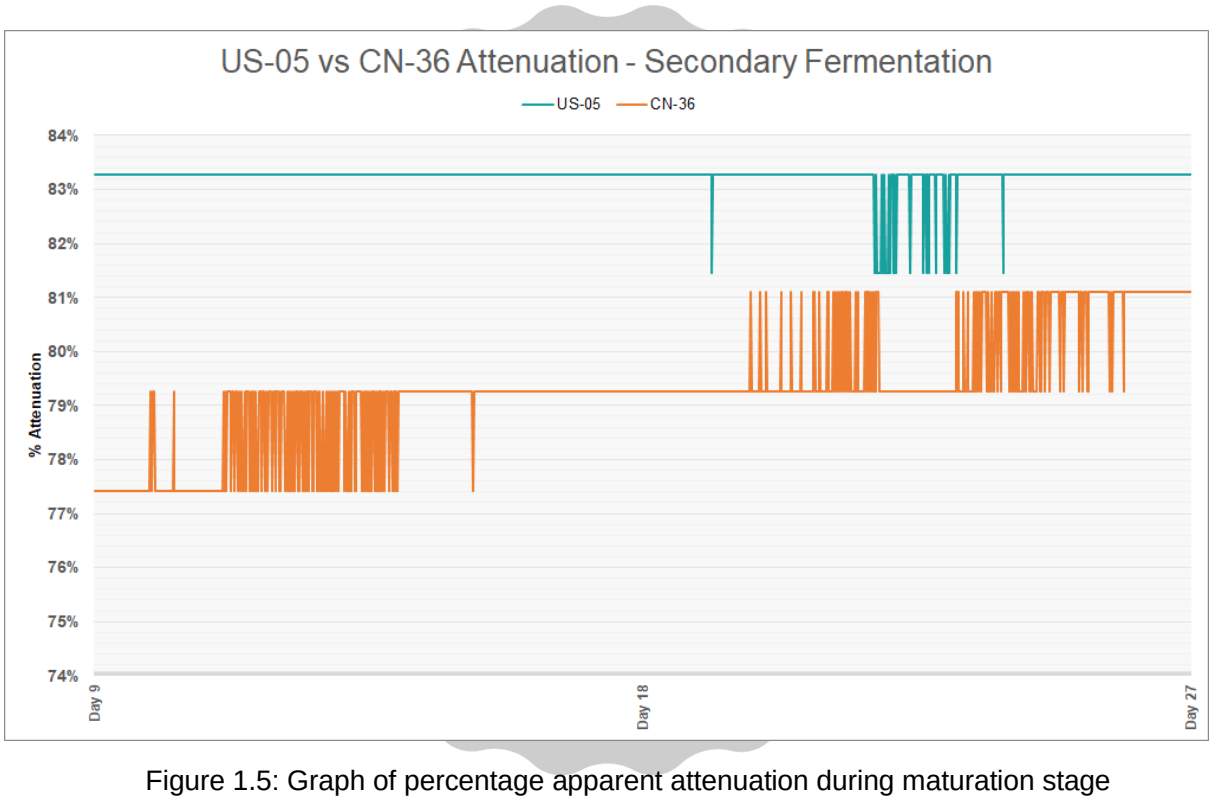


Figure 1.5: Graph of percentage apparent attenuation during maturation stage

During this process, the colour of both beers was observed to change, indicating a possible oxidation. Moreover, US-05 beer seemed to have an even darker colour compared to CN-36 beer.

To confirm this theory, EBC was determined through a fast test at 430 nm with a Genesys spectrophotometer coupled with BeerCraft software (by Thermofisher)[5]. Results confirmed that US-05 beer had a darker colour than CN-36 beer, 15.4 against 13.3 EBC. The possible reasons of oxidation during fermentation are possible gas leakage on the Fermentasaurus lids, or gas exchange due to the Fermentasaurus material properties. In addition, according to literature [6],

the direct cause of oxidation is mainly by aging. The oxygen conditions, storage temperatures and beer's ingredients could affect the speed and severity of oxidation. When the beer is left unattended for some time after fermentation, and stored at temperatures above 10°C, the risk of oxidation is increased.

4.6 CONDITIONING

After secondary fermentation was completed, the beers were transferred into kegs. Because of our facility regulations prohibiting gas cylinders left at the lab, the carbonation method used was "crank and shake" through forced carbonation. The desired and obtained pressure was set at 12 psi, achieving approximately 2.7 volumes of CO_2.

5 SENSORY EVALUATION.

Once the two beers completed the conditioning and maturation phase, they were compared against each other using a Triangle Test to gauge whether an overall perceivable difference was present between the two finished products. Following the completion of the Triangle Test, both finished products were evaluated individually using a Sensory Evaluation Method in a blind tasting format. A total of 13 panellists with ranging experience participated in both exercises.

5.1 TRIANGLE TEST

Each panellist was provided with three samples where two were identical and the third sample was of the other beer. For two products (Beer A and Beer B), six possible combinations exist; ABA, AAB, ABB, BAB, BBA, BAA. These six possible combinations were randomised across the panellists. The panellists were then asked to taste the beer from left to right and identify the odd sample. 12 out of the 13 panellists correctly identified the odd beer.

Additionally, the results were evaluated using chi-square distribution formula [B] and accounted for type I error. It was found that the null hypothesis stands true and there is a significant perceivable difference between the two finished products being compared.

Details:

Total answers = 13

Observed correct answers, O = 12

Probability of correct answers by chance, n = ⅓

Expected correct answers by chance, E = n(Total Answers) = 4.33

$\therefore$ Chi-square Distribution, $X^2 = 13.58$

Accounting for type 1 error, $\alpha=0.05$

From charts [B], $X^2_{1,\,0.05} = 3.84$

Since, $X^2_{1,\,0.05} < X^2$

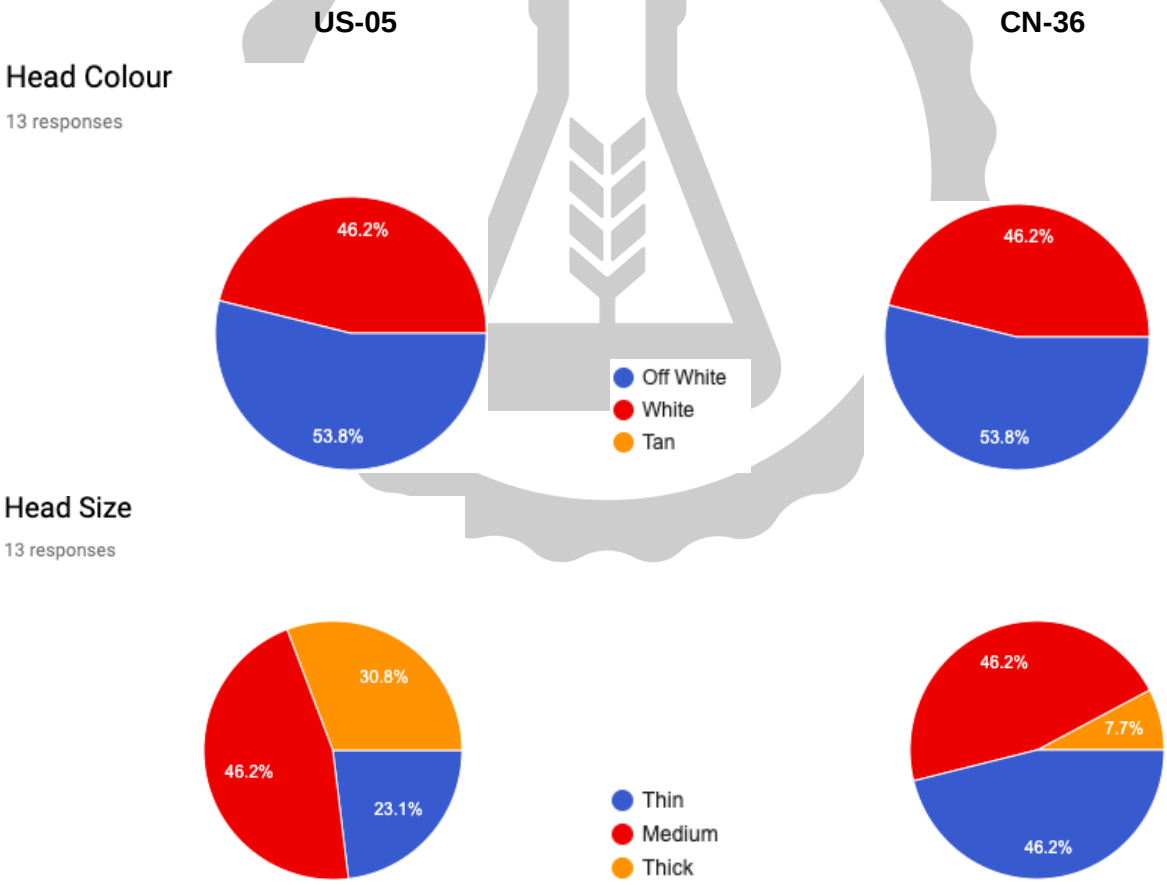
Null Hypothesis stands TRUE.

5.2 SENSORY EVALUATION

The sensory evaluation exercise was conducted to evaluate subtle aspects of the two beers relying on the perception of the panellists. The beers were served to the panellists one at a time without disclosing the name of the beer in order to eliminate all preconceptions that may otherwise be present. During the sensory evaluation, four major aspects of the beer were analysed; Appearance, Aroma, Flavour and Mouthfeel. Presence of flaws or off-flavours were analysed as a separate category since some flaws often tend to be multisensory.

The assessment of the beers appearance include factors such as its colour, clarity, head size, head retention, and head colour. The aroma and flavour of the beer combines to form its taste and are described using tasting descriptors. Lastly, the mouthfeel analysis of the beer includes factors such as finish type, finish length, body type, and carbonation. The results for analysis of all the above-mentioned factors are collated and summarised below.

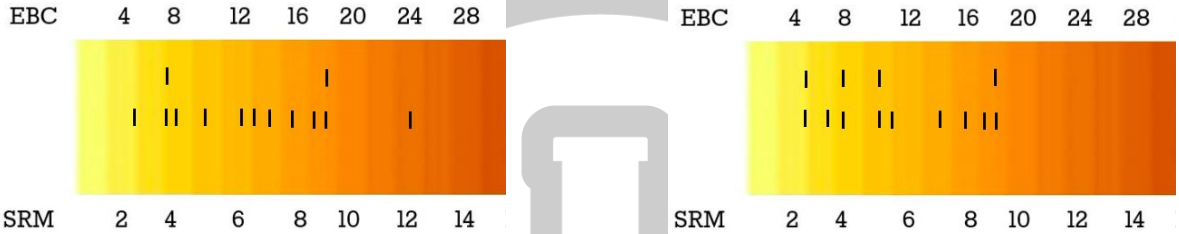
5.2.1 Appearance



Clarity

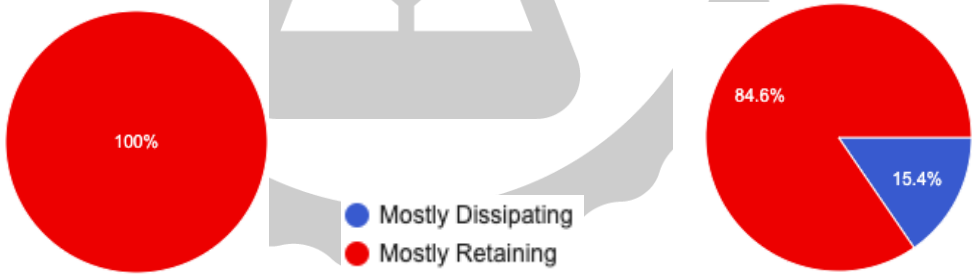
13 responses

Colour



Head Retention

13 responses

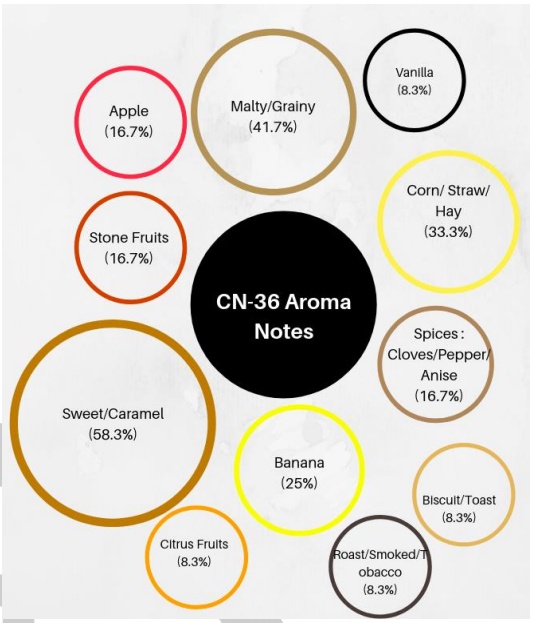


It can be inferred that there was no perceivable difference in colour of the head, with both US-05 and CN-36 beers having an off-white to white coloured head. Most of the panellists said that US-05 sample had a medium to thick sized head while the CN-36 sample had a medium to thin head. 100% of the panellists agreed that the US-05 sample had good head retention as compared to 84.6% for CN-36 sample. However, this could be due to the fact that US-05 was analysed first while CN-36 was already poured, hence resulting in longer resting time for the CN-36 sample. CN-36 sample was believed to have greater clarity in comparison. Slight variation existed in predicting the colour of the two beers with most entries being between 4-20 EBC for both beers. However, CN-36 sample was believed to be slightly lighter in colour in comparison to US-05.

5.2.2 Aroma

US-05

CN-36

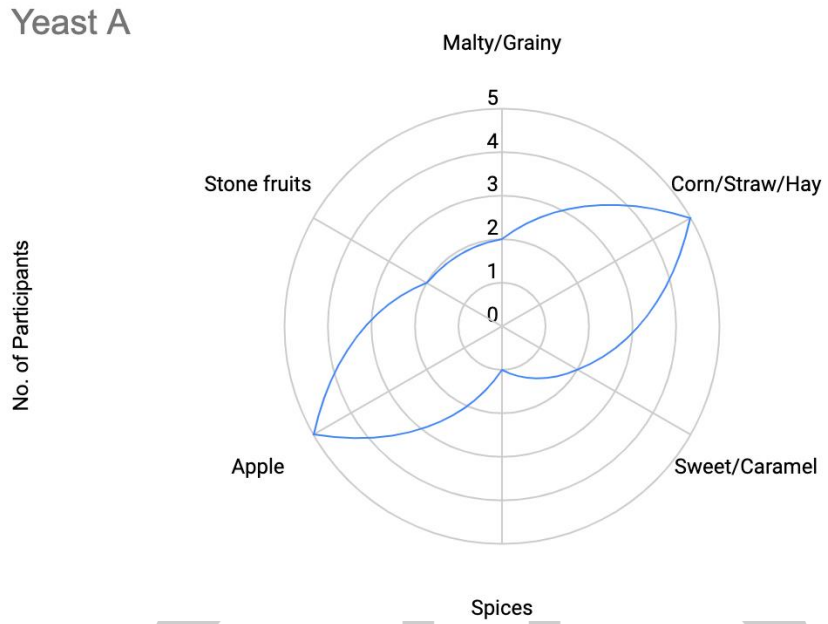


In terms of the aroma profile for both samples, US-05 had sweet/caramel, banana, apple and corn/hay/straw as the most dominating notes while malt/grains, vanilla, stone fruits, roast, spices and citrus fruits as secondary notes were also detected.

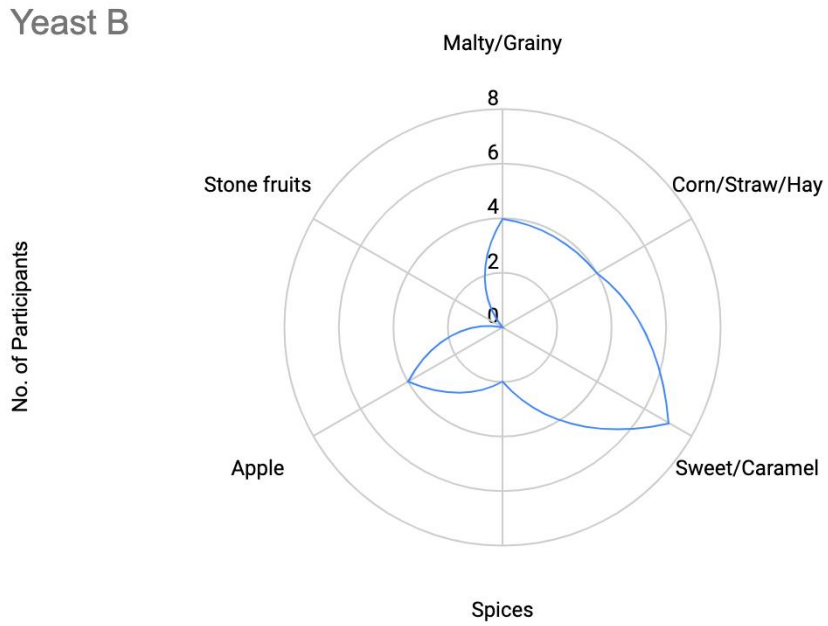
In comparison, the CN-36 sample had similar primary notes of sweet/caramel and corn/hay. Unlike the US-05 sample, CN-36 had primary notes of Malts/Grains while perception of banana and apple was weaker. Secondary notes for CN-36 sample were identical to US-05 with stone fruits, spices, citrus fruits and vanilla with addition of biscuit/toast aroma notes.

5.2.3 Flavour

US-05



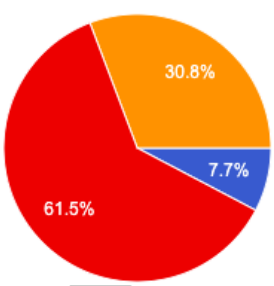
CN-36

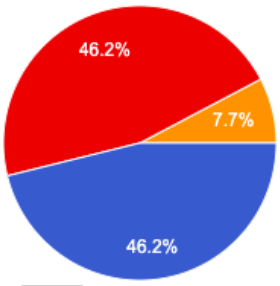


US-05 **CN-36**

Perceived Bitterness

13 responses

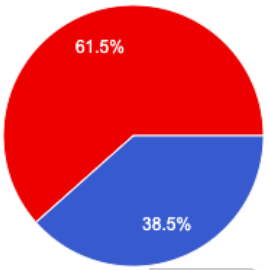


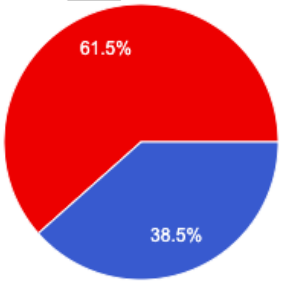


Low (1-30 IBUs)
Medium (31-70 IBUs)
High (70+ IBUs)

Apparent ABV %

13 responses



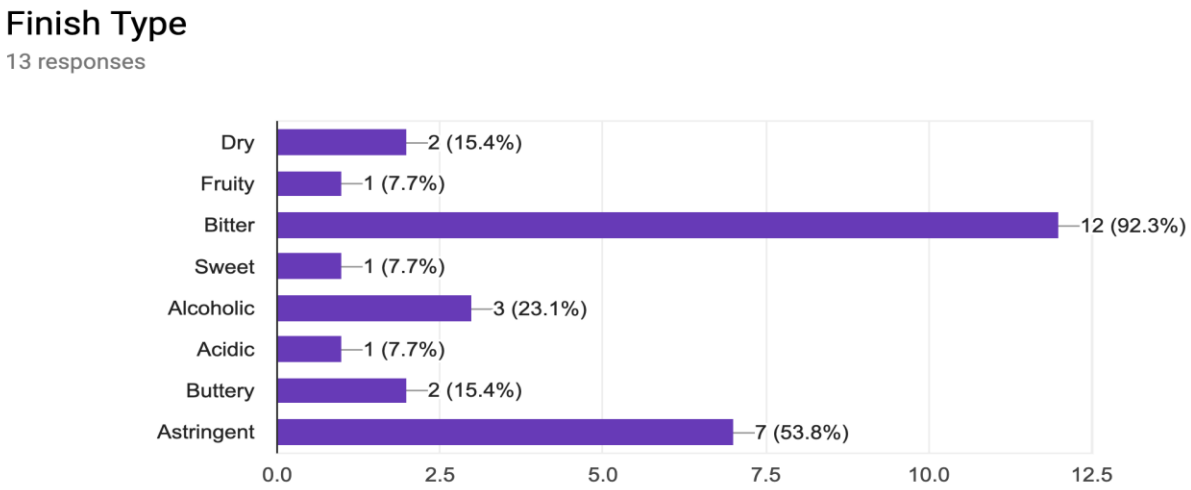


4% or less (Light)
4 to 7% (Medium)
7% or more (Heavy)

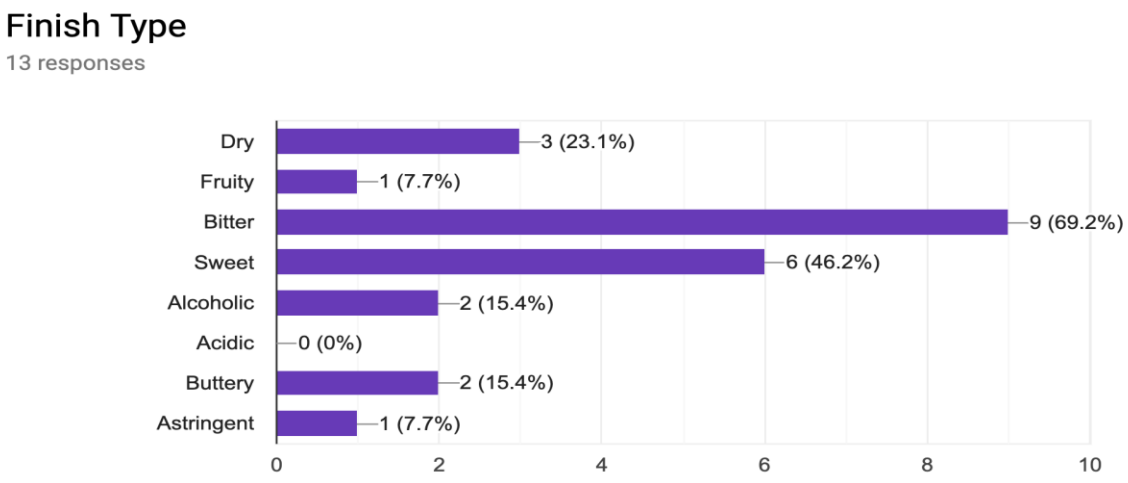
The aroma notes directly carry forward to the flavour notes of the two samples. Apple and corn/straw/hay were the most dominant flavour notes for US-05. Sweet/caramel and banana add to the flavour profile. For CN-36 sample, sweet/caramel flavour dominates, with apple, malty/grainy and corn/straw/hay notes round off the flavour profile. In addition to the flavour notes, US-05 sample was perceived to have higher bitterness as compared to CN-36 sample. Lastly, both the beers had identical alcohol presence according to the panellists.

5.2.4 Mouthfeel

US-05



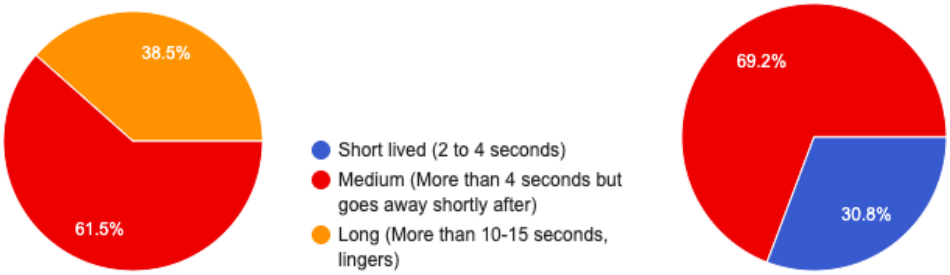
CN-36



US-05 **CN-36**

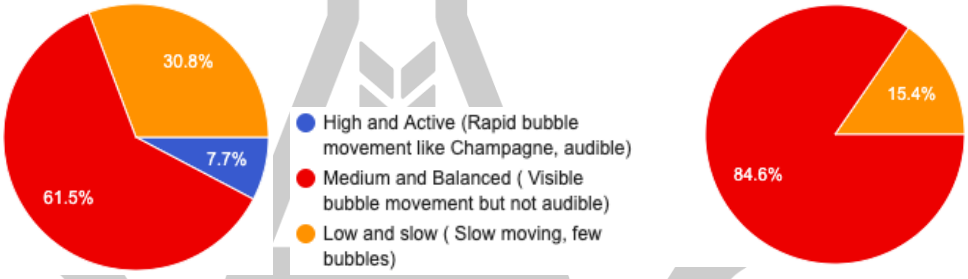
Finish Length

13 responses

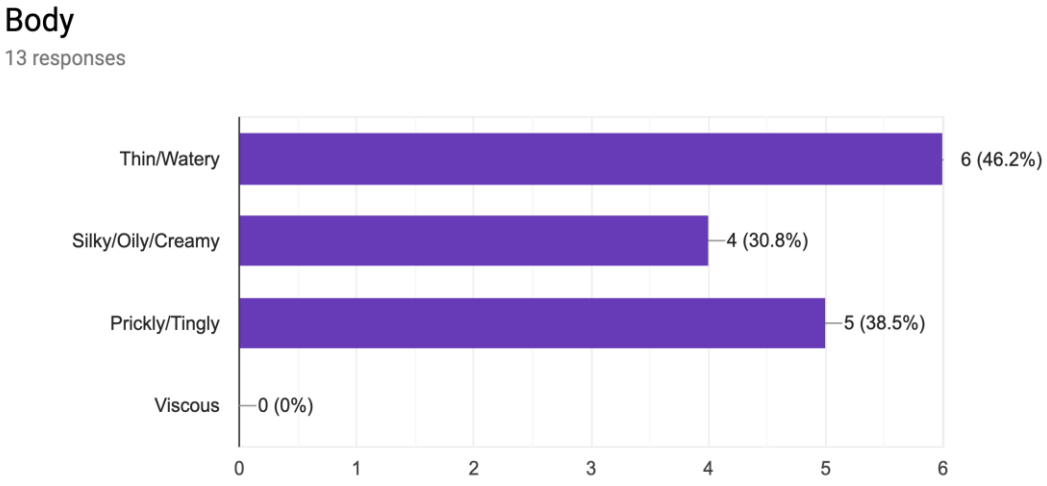


Carbonation

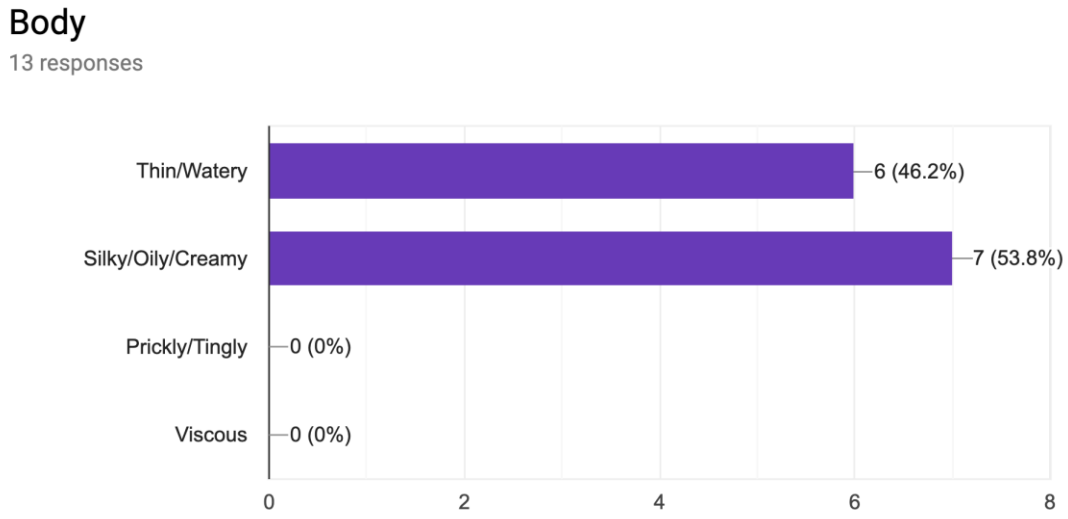
13 responses



US-05

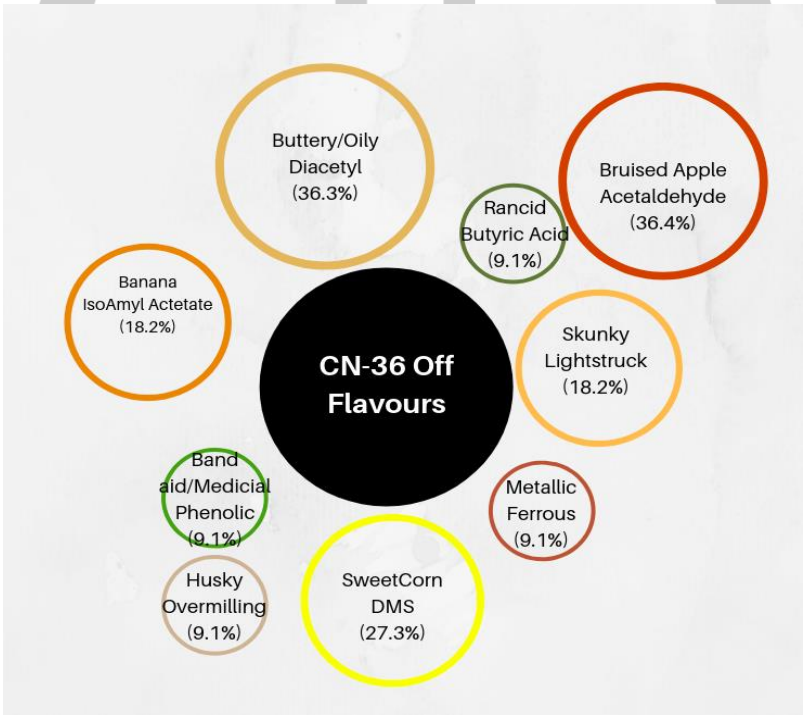


CN-36



The US-05 sample had a mostly bitter and astringent, medium to long finish while the CN-36 sample was perceived as bitter, sweet and slightly dry in its finish. CN-36 had a shorter finish as compared to the US-05 sample. CN-36 sample was also believed to have better carbonation as compared to US-05 sample. In terms of the body of the beer, both the beers were perceived as thin and watery. CN-36 had additional silky/oily mouthfeel while US-05 was perceived to be prickly/tingly as well as silky/oily.

5.2.5 Off Flavours



Both beers had a strong presence of a number of off-flavours. Bruised/green apple was the most common flavour in both beers indicating presence of acetaldehyde exceeding the threshold limit. Additionally, both the beers had similar amounts of diacetyl. Some panellists detected DMS and huskiness in CN-36, while US-05 had noticeable oxidation damage, which was not present in the CN-36 sample.

5.2.6 Judge impressions

To further strengthen the sensory analysis, two of our highest experienced members with professional judging experience analysed the two beers in a blind tasting format following BJCP guidelines. While the rest of the judging format was kept identical to BJCP procedure, scoring of the beers out of 50 was omitted for this exercise. The judging notes are as follows.

US-05

Judge 1

- Appearance: Golden pale hue, slightly less clear than the CN-36. Persistent white-off head.
- Aroma: Little to no grain or malt, aromas of acetaldehyde and diacetyl dominate, astringent prickly undertones, hints of herbal spices. No hop aroma.
- Flavour: Pale malt barely noticeable, harsh acetaldehyde overpower, big presence of diacetyl leaves a buttery musky character. No hop flavour. Bitterness very present, but may come more from the astringency than the bittering hops. Medium herbal dry finish.
- Mouthfeel: Oily, buttery, and astringent mouthfeel. Aftertaste is harsh and lingering. Carbonation is well balanced.
- Impression: There are major flaws perceived, namely diacetyl, acetaldehyde, and oxidation. Possible presence of oxygen during fermentation and absence of diacetyl rest may have had this effect.

Judge 2

- Appearance: Yellow/Golden colour, mostly clear, thick white colour head, good retention
- Aroma: Starts of sweet followed by grainy notes, quickly interrupted by sharp acetaldehyde. Mild to none hop aroma, slightly pungent aroma.
- Flavour: Mild maltiness, initially sweet but sharp apple seed bitterness cuts through, quite bitter but not from hops, no hop flavours, no pleasant yeast character. Papery oxidised.
- Mouthfeel: Leaves the mouth dry, with sharp lingering bitterness, long finish, and thin mouthfeel. Carbonation level is good which keeps the beer lively on the palette.
- Impression: Quite a lot going on with noticeable off flavours, fermenting at a lower temperature and preventing oxidation will help hops take the show window. Excessive Acetaldehyde being the major flaw.

CN-36

Judge 1

- Appearance: Golden, slightly less pale, hue. Clearer than US-05. Persistent but slightly thinner white-off head
- Aroma: There is a mild undertone of esters and malty character. Acetaldehyde and diacetyl still present but in much lower magnitude. Herbal and very slightly floral spices perhaps coming from hops.
- Flavour: Flavour profile follows the aroma. Diacetyl is more evident, leaving a butterscotch finish as well. Bitterness is more akin to style. Hints of summer ale more perceivable.
- Mouthfeel: Slightly thin mouthfeel, but fresher. Medium balanced carbonation.
- Impression: The flaws are still present, but at a lesser degree. This is more enjoyable, but still needs work

Judge 2

- Appearance: Golden yellow colour with a touch of caramel, crystal clear, thick white coloured head. Head retention is fair to good.
- Aroma: Pale malt shines through, sweet grainy undertones, not much hop presence with only hints of stone fruits. Acetaldehyde still present but much less offensive. Mild peppery/Herbal esters.
- Flavour: Sweeter than US-05, esters more prominent than hops, slight spice present. Acetaldehyde fails to hide, mild phenolic and sulphur skunk.
- Mouthfeel: Buttery and oily slickness yet quite thin and fast moving. Medium to short finish, active and lively carbonation.
- Impression: Lesser offensive off flavours let the malt base shine more. Hops could be utilised better. While acetaldehyde does not shout out in this one, it still alters considerably the overall impression of the beer.

6 CONCLUSIONS.

Accordingly to the results of this experiment, it is concluded that CN-36 has a faster rate of fermentation as compared to US-05 despite US-05 having commenced the fermentation process earlier than CN-36 yeast.

The final gravity of US-05 sample after primary fermentation was 1.009 which is lower than that of CN-36, 1.012 after primary fermentation. However, during secondary fermentation the gravity of US-05 sample stays constant while that of CN-36 sample decreases a few points from 1.012 to 1.010 indicating that CN-36 yeast still breaks down sugars at lower temperatures and is overall a more aggressive acting yeast.

CN-36 yeast was also found to produce lower amount of acetaldehyde when compared to US-05 or has a better ability to reabsorb the acetaldehyde produced during fermentation as compared to US-05, leading to a cleaner profile which can be inferred from the sensory evaluation results. Although the CN-36 yeast was found to have higher flocculation and clumping of yeast in comparison, this did not seem to affect the clarity of the finished product with both samples having similar clarity according to the sensory evaluation results.

Therefore, CN-36 proved to be a more vigorous and faster fermenting yeast with higher flocculation and high attenuation. It also had a cleaner flavour profile when compared to US-05 with addition of mild ester presence which was absent in the US-05 product making it a universal and largely applicable product.

7 FUTURE WORK AND IMPROVEMENTS.

There were oxidation problems during fermentation, as noted in the change of colour during secondary fermentation and in the off-flavours perceived in the sensory evaluation. To provide a more reliable comparison without off-flavours and to increase the accuracy of statistical conclusions, more experiments of the same nature are encouraged to be carried out between the two yeast strains in brewing different styles.

8 REFERENCES.

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