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Study of Volatile Compound in Wort Boiling

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Abstract : The wort boiling is the important step in a beer making process. Beer industry is facing two challenges, energy consumption particularly thermal energy and water consumption. Present work reduces thermal energy required for the process. Wort boiling process improves wort colour, odour, gravity, taste, sugar concentration. It improves beer quality. In present study comparison of wort process parameter of atmospheric wort boiling and boiling under vacuum was done. Wort boiling under vacuum gave good results over atmospheric boiling.
Keywords : Wort, Boiling, Volatile removal, DMS.

1. Introduction

In beer manufacturing process, the brew house section plays important role which decides proper chemical composition, taste and alcohol percentage of beer. Wort boiling is an important process as it helps in controlling the overall final quality of beer. There are different types of methods for wort boiling like atmosphere boiling, boiling under vacuum, boiling under pressure etc. The brew house involves first mashing process, where complete degradation of starch to sugar is obtained. Soluble dextrin and most of the extract from mash was produced during mashing by the action of enzymes. Second most important step is wort separation, where wort is separated from grains in liquid form. To collect maximum extract from grain, hot water is used for washing of grain. Wort gets diluted because of hot water. In boiling of wort, wort was concentrated by evaporating water present in it. During this step various activities were incorporated like hops addition, removal of unwanted components and formation of proteins (Trub). In the next step there is increase in the level of volatile material particularly DMS, which was removed. The last process of brew house is wort cooling, where hot wort is cooled to 8-10 ^{0}C. The next step is addition of yeast and oxygen for fermentation. Wort sterilization will result in destruction of all enzymes which were active during conversion of modified starch to sugar. If pH of the process is lowered then it will form reducing substance [1].The sources of dimethyl Sulphide (DMS) in beer and their relative significance to levels of DMS which are produced under various brewing conditions were studied [2, 3]. The researchers have thrown light on wort boiling objectives, importance of wort boiling, different type of wort boiling, their advantages, disadvantages and energy saving with respect to different type of boiling [4]. The wort boiling performance and the energy required for wort boiling was studied [5]. Evolution of volatile compounds during wort boiling was studied [6]. Diatomaceous earth has large contribution in the brewing waste.Dose of diatomaceous earth was reduced through beer filtration using carrageenan at the phase of wort boiling. The beer treated with carrageenan and before treatment was compared. In treated beer lower haze was observed as compared untreated beer [7].Boiling systems with low thermal stress in combination with volatile stripping was discussed. Different technologies of wort boiling were studied with the reduction in thermal energy [8, 9].The wort boiling process can also reduce the different metal content level in wort like nitrogenous (proteins and amino acid) of the finished beer was studied [10]. The relationship of Dimethyl sulphide levels in malt, wort and beerwere discussed with help of different methods [11].Formation of foam and

its stability was decided by contact between beer proteins alpha acids. The major factor which decides the wort boiling is the temperature. The researchers studied the relation of temperature and sea level on formation of final beer [12]. During boiling the samples of the wort was analyzed for its different compounds. Total 118 compounds were recognized for boiled wort. To know the quality of wort,it's very important to know the compounds present in it [13].Treatment of wort boiling should be homogeneous. New method for wort homogeneity was proposed which gave improved predictions of reactions and wort boiling processes [14]. Effect of mashing temperature on bitterness, pH, colour, CO_2 and polyphenol content was observed. Content of total polyphenol was less in pale beer as compared to dark beer. Increase in haze was observed for all beers when proteolysis was done [15]. Instead of boiling wort, it was hold for 85^0C. Effect of holding on beer quality was observed. Shelf-life and flavour was same when beer was hold [16].Development of new test was done for chilled break performance of malt depending on mashing and boiling. Copper finings concentration was changed for different pH range. After finishing all steps pH of the wort was increased, this improved the performance [17]. Wort boiling time was varied from 15minutes to 2 hours others parameters were kept constant. Content of DMS in beer was changed with respect to time. When wort was fermentedusing two different strains, DMS levels were changed even if time was varied [18]. Different heating media used for wort boiling and their advantages were mentioned in detail and concluded that with necessary precautions steam heating is better than other heating method[19]. Good wort boiling depends on the highest possible temperature, A vigorous and continuous blowing, and the maximum amount of heat transfer at any given time was discussed. The material properties of metals like thermal conductivity and specific heat and effect on wort were also mentioned [20]. During wort boiling four fractions, designated to T, C, O, D has been separated from wort by precipitation with ammonium sulphate. Each fraction having his own properties which depend on its original sources and the condition of precipitation [21]. Properties of Coagulable protein of sweet wort had discussed in detail [22]. It was observed that characteristic of beer depend on various factors such as pressure, temperature and time during wort boiling [23]. The objective of wort boiling concepts and different boiling process like low pressure boiling, thermovaporrecompression(TVR) boiling, high temperature wort boiling, dynamic low pressure boiling, boiling with internal and external reboiler, volatile stripping from wort after boiling, modern boiling system and evaporation of volatiles were discussed with help of diagram[24,25].Importance of wort boiling was discussed[26]. Authors have discussed nitrogen compound in wort composition, its effect on brewing and final beer shelf life [27]. The Improvement of the wort manufacturing processes and the parameter to be monitored during wort boiling and cooling were discussed [28]. Author has discussed the different methods which were used for wort boiling like traditional direct fired kettle, kettle with external wort boiler, internal heating system, external heating jackets etc [29]. Different aspects of beer stabilisation and their importance on beer shelf life have discussed [30]. DMS Stripping in brew house has been discussed in detail [31]. Author had discussed the main resources of brewery like water and energy consumption [32]. The chemistry of wort boiling with required process parameter and other fundamentals of wort boiling process was studied [33].

In this research work we have studied different wort boiling process and method has been discussed.New boiling technique was proposed to replace the traditional boiling process.All parameters were studied to meet the quality of wort and compared with the traditional one.

2. Experimental

In traditional process, wort after boiling was transferred to whirlpool in whirly action. In the whirlpool the rest for 10-20 minutes was given to separate the protein/ trub and after rest transfer to fermenter through cooler. During this rest the rise of unwanted material was observed in PPM level; to avoid this rise of unwanted material vacuum flashing is suggested before wort cooling as the temperature is decreased during rest so at lower temperatureflashing can be achieved by using vacuum and with addition to reduction in unwanted material slightly evaporation also occurs. And due to same in reduction of the main evaporation percentage during main wort boiling so that total evaporation will be same in the new system (vacuum flashing) and hence lower steam consumption is achieved as compared to the traditional one.

In traditional way wort boiling process, Wort is boiled at 100^0C for 60-75 minutes to achieve the evaporation rate 4% to 12%. Then wort was transferred to whirlpool to separate the protein. In whirlpool after transfer rest was given to wort to settle down the solid particles; then wort was transferred to fermenter through wort cooler.

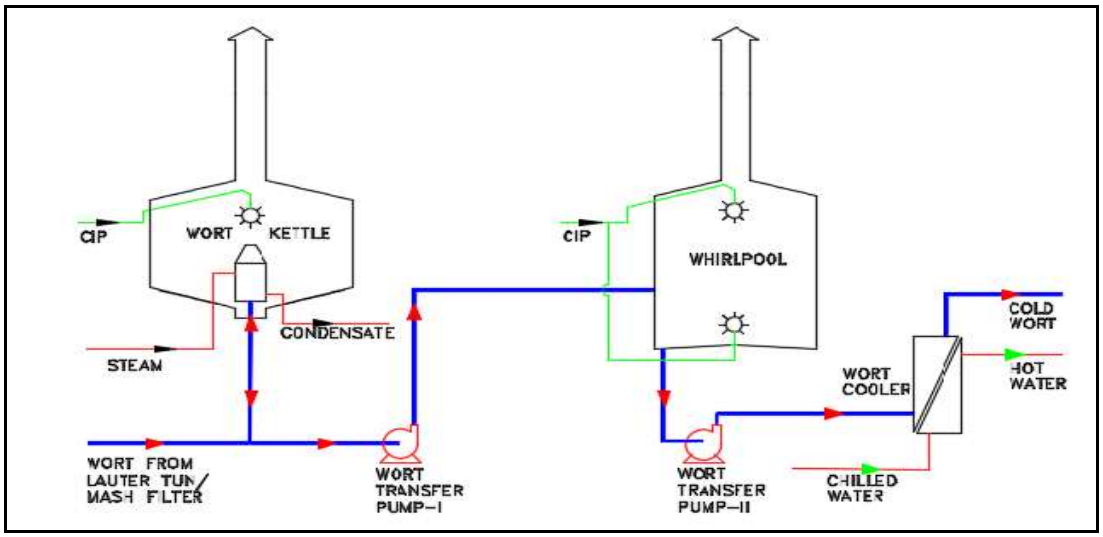

Figure 1: Traditional way wort boiling i.e. atmospheric wort boiling

As per the new proposed way, wort was boiled at 100^{0}C for 45-60 minutes to achieve the evaporation rate 2% to 10%.Then wort was transferred to whirlpool to separate the protein. In whirlpool after transfer rest was given to wort to settle down the solid particles. Then wort was transferred for cooling through wort flash system; where vapour liquid separator operated under vacuum, so that with the available temperature, remaining approximately 2% boiling was achieved.

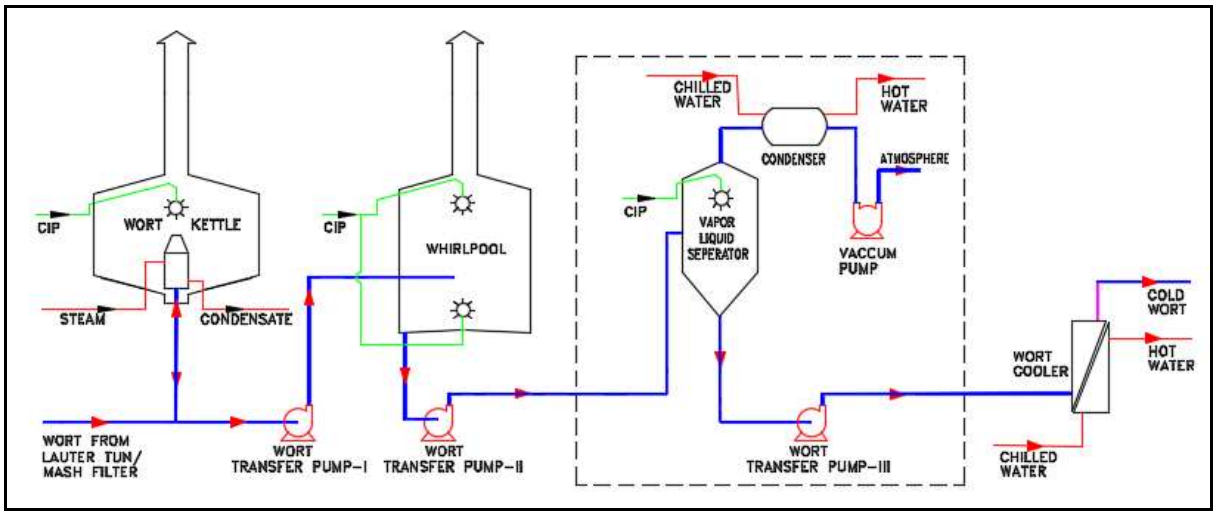

Figure 2: New proposed way of wort boiling

Wort extract (65% Indian barley malt and 35% broken rice) collected from Indian industrial brewery, Mumbai was used for experimentation.Following apparatuses were used for the experimentation. Heating mental specifications were mentioned as, temperature range 150^{0}C, 0.75 KW. Boiling Flask capacity was 1.5 liter. Vacuum pump of capacity 0.5 AM3/Hr 430 mm of Hg was used.

Total six trials were carried out for below mentioned boiling process for comparison of wort parameter.

Type -1: Normal regular wort boiling (Traditional Boiling) – Wort was boiled at 100^{0}C and achieved 6% evaporation.

Type -2: New proposed way – Wort was boiled at 100^{0}C and achieved 4% evaporation. After that wort was hold for 30 minutes (This 30 minutes considered as casting time and rest time in whirlpool) at same condition without heating apply the vacuum at available temperature and achieved remaining 2% evaporation.

For wort analysis Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), EBC colour meter (Range 0 to 20 EBC), Gravity Meter (Range 0 to 20 degree Plato), Hydrometer (Range 0 to 20 degree Plato), pH Meter (Range 0 to 14) is used.

3. Results and Discussion

3.1 Energy Saving

Considered 100 hl (cold wort) brew length with 6 % total evaporation and 4% contraction ratio.
Hot wort after boiling = 100 hl / (1-(4/100)) = 104.17 hl (Considering 4% Contraction ratio)
Hot wort before boiling = 104.17hl / (1-(6/100)) = 110.82 hl (Considering 6% Evaporation)
Evaporation rate =110.82 x 0.06 = 6.65 hl / brew (Considering 6% Evaporation)
Steam required = (6.65 hl x 100 kg / hl x 540 kcal / kg) / 520 Kcal /kg considering 1.5 bar (Gauge) Steam pressure = 690 kg / Brew steam is required if we are doing boiling by traditional way.
Hot wort before boiling = 104.17 hl / (1-(6/100)) = 110.82 hl
Evaporation rate = 110.82 x 0.04 = 4.433 hl / brew

Steam required = (4.433 hl x 100 kg / hl x 540 kcal / kg) / 520 Kcal /kg considering 1.5 bar (Gauge) Steam pressure = 460 kg / Brew steam is required if we are doing boiling by proposed way & remaining 2% boiling will be achieved by vacuum.

But in proposed way to achieve vacuum, vacuum pump and water pump for condenser is required so approximately 11kw per hour electricity is required.

11 KWH x 7.5 Indian Rupees / KWH =82.5 Indian Rupees / brew additional cost is required.
Steam saving will be = 690 kg – 460 kg = 230 kg / brew
Considering 1 Indian Rupees / Kg steam cost; we can save 230 Indian Rupees / Brew in proposed way.
Total saving will be 230 – 82.5 = 147.5 Indian Rupees / Brew
So approximately 147 Indian Rupees we can save per brew.

3.2 Analysis of wort

Table1 shows the analysis of wort by traditional one and by new proposed way.

Table 1: Wort Parameter comparisons between traditional way boilingwort and vacuum boilingwort

Sr. No.	Parameter	Unit	Regular boiling 6% evaporation	Regular boiling 4% hold 30minutes again flashing 2% under vacuum
1	pH		5.11	4.83
2	Total solid	%W/W	16.43	16.83
3	TBN (Thiobarbituric Acid Number)		7.2	12.5
4	Colour	EBC	7.67	7.72
5	Specific Gravity	PPM	1.0657	1.0673
6	TKN (Total kjeldahl Nitrogen)	PPM	8500	8500
7	FAN (Free Amino Nitrogen)	PPM	225.775	230.799
8	Total Polyphenols	PPM	129.56	134.98
9	Acetic Acid	PPM	464.4	431.64
10	Dimethyl Sulfide	PPB	26.64	NIL
11	Propionic Acid	PPM	NIL	6.9
12	Iso-Butyric Acid	PPM	10	35.92
13	n-Butyric Acid	PPM	NIL	7.1
14	Acetaldehyde	PPM	24.45	23.94
15	Methanol	PPM	2.54	3.08
16	n-Propanol	PPM	1.53	1.69

Dimethyl sulphide in new proposed way was almost nil compared to traditional boiling wort. Other major parameter like specific gravity, colour, pH, TKN, FAN and polyphenols were almost same in both wort.

Table 2: Energy saving comparison between traditional way wort boiling and vacuum wort boiling

Sr. No.	Parameter	Unit	Traditional way Boiling	Proposed way of boiling
01.	Steam	Kg	690	460
02.	Electricity	KWH	Nil	11

Less thermal energy and more electrical energy required in new proposed way compared to traditional way.

Table 3: Overall comparison between traditional way wort boiling and vacuum wort boiling

Sr.No.	General Points	Traditional system	New Proposed system
1	Energy requirement	High	Low
2	Product Quality	Good	Very good compared to traditional way
3	Temperature	Need to maintain with help of steam flowrate	Initially need to maintain with help of steam and after that with available temperature vacuum to be maintain accordingly
4	Time of Batch/Brew	Standard time	No additional time is required
5	Power	Low	High
6	Space	Less space is required	More space is required

Considering all above mentioned points, new proposed way of wort boiling is sizable better than traditional way wort boiling for quality and energy saving point of view.

4. Conclusion

Different wort boiling process and method have been discussed and new boiling technique was proposed to replace the traditional boiling process. All the parameters were compared for both processes. Final beer quality was better in the new proposed one technique than the traditional one. Energy saving was observed in the new proposed process. Economically also it was more beneficial.

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