Thermal Aspects of Non Alcoholic Carbonated Drinks Processing

Jitendra Hemwani[1] Gagan Malik[2] Yatna Bhagat[3]
[1]Head of Department [3]Lecturer
[1,3]Department of Mechanical Engineering
[1,3]Govt. Polytechnic College, Betul, Madhya Pradesh, India [2]Varun Beverages Ltd. Saoner, Dist. Nagpur, Maharashtra, India

Abstract— The soft drinks consumption is increasing day by day, not only in India but in the whole globe. To meet out the growing demand of the market of soft drinks, new industries for the processing of the soft drinks must be set up. This paper gives the overview about the basic Production Process involved in making "Carbonated water-based flavoured drinks", which has the largest market share in all the non-alcoholic drinks. The basics of mixing of the ingredients at specified temperatures, carbonation of the mix to make beverage and then packing in bottles or cans and then dispatching for consumption, are given in this paper. Some information regarding utility services of the plant is also provided.

Keywords: Industrial Refrigeration, Production Process of Non-Alcoholic Carbonated Drinks, Soft Drinks, Water Based Flavoured Drinks

I. INTRODUCTION

The non-alcoholic beverages, commercially called soft drink includes soda water, fruit & vegetable juices, fruit & vegetable nectars, water-based flavored drinks including sport drink, energy drink, electrolyte & particulate drinks. The coffee, coffee substitutes, tea, herbal infusions, and other hot cereal and grain beverages are also included in the soft drink. The PepsiCo, Coca-Cola Corporation, Red Bull, Suntory, and Keurig Dr Pepper are the main manufacturer of the soft drinks. The survey by statista [1] shows that the average volume consumption per person in the soft drinks segment in India is 3.9 litres in year 2020. The total volume consumption in India will reach 637.63 crore litres by year 2025 i.e. 5.1 liters per person (considering population constant as 125 crores).

Thus to meet the increasing demand there is opportunity for entrepreneurs to set-up the soft drink bottling (manufacturing) plant. The Safety of the machinery, and hygiene requirement of the plant and the design of the food processing machinery should be maintained as per ISO 14159: 2008.

Following typical flow chart in fig.1 shows the basic production process involved in the soft drink manufacturing.

II. WATER TREATMENT

The Water quality is very important to get the success of carbonated non alcoholic drink. Suspended particles, organic matter, and bacteria like impurities may degrade taste, colour and shelf life of the drink. The water is sterilized to destroy the bacteria and then sufficient doses of free chlorine are given to maintain free residual chlorine level. The impurities from the water are mainly clarified by traditional methods like chlorination, physical filtration, and Reverse Osmosis (RO) or coagulation processes. The ferrous sulphate is mainly used for coagulation process. Sometimes hydrated lime is also added to get desired pH level and alkalinity, which is generally maintained as (2P – M) between +2 to +7, where P and M are the alkalinities, which are classified according to the endpoint of titration with strong acid. P alkalinity is the Carbonate alkalinity with endpoint HCO_3. M alkalinity is the total alkalinity with endpoint CO_2.

Now this clarified water is passed through a layer of sand filter. The flow velocity of the water depends upon the cross-sectional area of the sand bed, generally it is kept as 80 litre/min/m^2. This sand filtered water is passed through activated carbon filter to remove the residual traces of the pesticides and the traces of chlorine. The flow rate of the water in the activated carbon tank is generally kept 160 litre/min/m^2. Now the water is passed through micron cartridges and then through ultra violet chamber.

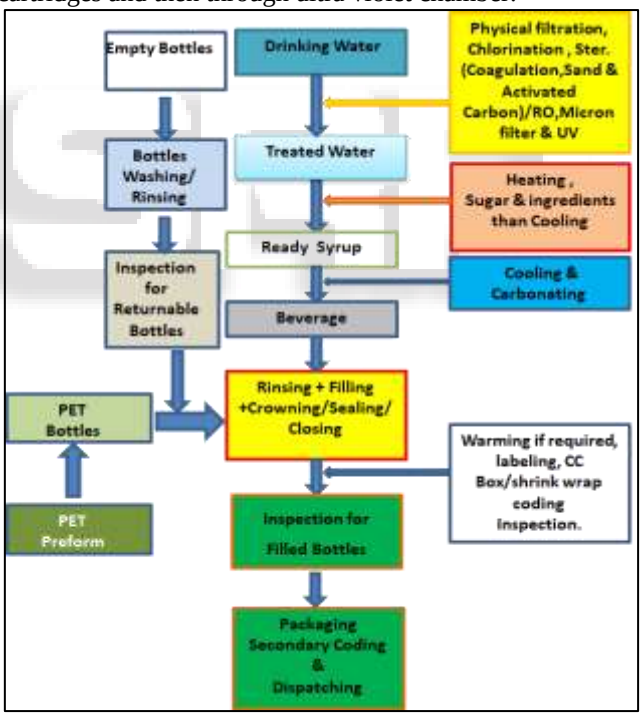

Fig.1: Flow Chart for Production Process

III. SYRUP MAKING

Syrup is the solution of sugar in water. Sugar is one of the main ingredients of the non alcoholic sweetened carbonated beverages. Sugar used is approximate 8 to 12% of weight/volume in the soft drinks. Sugar to be added should fulfill the standards of quality regarding physical or chemical properties. Sugar in solid or liquid form is added to the heated water & activated carbon powder (0.2% of the quantity of sugar) to form Raw syrup. Generally final temperature of the Raw Syrup is around 80℃. At this temperature the contact time of 30 minutes is given to

carbon powder and raw syrup, which remove the color from the syrup and absorbs residual/traces of the pesticides of sugar.

IV. MIXING OF INGREDIENTS

The main ingredients of the water based non-alcoholic carbonated drink (beverage) are Treated water, Sugar, Flavoured Concentrate, and CO_2 (Carbon dioxide) or Pulp Concentrate. And some other ingredients are also added in water based non-alcoholic carbonated drinks as additives if required to give flavours or aroma, colours, taste, sharpness (for background taste), foamy head, eye appeal. In low calories drinks, sugar free for sweetness to give mouth feel and preservatives to minimize the risk of microbial spoilage, are sometimes also added if necessary.

Philip R Ashurst [2] stated that "The ratio of sweetness to sharpness decides the taste characteristic of the soft drink. The above said ingredients are mixed as per requirement of the taste, flavor, sweetness, tartness and shelf life of the soft drink".

This Raw syrup is filtered in physical filter press to remove suspended particles and activated carbon powder. In typical application the Raw Syrup is cooled in two stages. In first stage it is cooled from 80℃ to 40℃ temperature by cold water of the overhead cooling tower. Then in second stage it is cooled from 40℃ to around 21℃ temperature with the help of industrial refrigeration system. At this temperature the transparent and filtered Raw syrup is supplied in to the dose (batch) tanks where the concentrate and other ingredients are carefully mixed with the Raw syrup to make Ready syrup. The quantity and type of the ingredients and flow rates are controlled as per requirement of the type of soft drink to be produced. But Nutritional and health value for products are very tightly controlled by Food Safety and Standards act 2006, governed by Food Safety & Standards Authority of India (FSSAI). The Food companies have to take the certificate "FSSC 22000", which contains a complete certification scheme for Food Safety Management System.

The pasteurization is necessary when the fruit juice is used as ingredient in the beverages because it provides improved safety and microbial spoilage protection. The pasteurization is not needed when simple flavored water based non alcoholic carbonated products are manufactured at a good hygiene facility.

V. CARBONATION

Carbonation means adding the carbon dioxide gas to the blend of Ready Syrup and deaerated treated water. The ready syrup is generally around 21℃. The carbonation in the product is optimum at low temperature around 2℃ to 7℃, hence it is always carried out at low temperatures. The carbonation can be classified in two systems—

A. Premix system:

In this system Ready syrup and treated water required for beverages are mixed then the final volume of product is cooled to 2℃ to 7℃ and then the CO_2 is added. Carbonation machine is shown in fig.2.

B. Postmix system:

In this system the Ready syrup, which is approximately 15% to 20% of final product volume is cooled. Then separately cold water is carbonated in required proportion and mixed with this ready syrup such that the final temperature remains around 2℃ to 7℃.

Whether carbonation is done by Premix or Postmix system, following factors are considered.

- Air and Oxygen ingress must be kept to an absolute minimum in water & beverages,
- Mixing should be very carefully controlled so as to avoid vortexing or other operations which draw air into the mix.
- After ensuring the mix complies with required quality parameters it is then carbonated.
- The final product carbonated beverage is then fed to the filler.
- Counter-pressure fillers are also used. A fluid level in the container is the foundation of a filling method.

Fig. 2: Carbonation Machine

VI. BOTTLING

The above carbonated soft drink is transferred into bottles or cans at very high speed rates. The net content of the drink in the bottle should comply the legal metrological act 2009 and legal metrology (Packaged commodities) rules 2011. To reduce the loss of CO_2 during capping or sealing the product is filled at low temperature, around 2℃ to 7℃. The Bottling is done in following three types' containers.

A. Glass Bottles:

Generally, Glass bottles are preferred not only in carbonated beverages but also in other applications because they give a brand image and enhanced shelf life. The metal caps without threads are pressed on the bottle. This requires a rotating chuck to press it tightly. The cap having a Poly Vinyl Chloride (PVC) and Non PVC sealant is used to get the gas tight seal. But the main disadvantage of glass bottles is its brittleness and heavy weight.

B. Cans:

Preprinted, non-corrosive Aluminum cans produced by drawing and wall ironing are used for carbonated beverages packing. The can ends are pressed after filling the drink. The

data regarding the product i.e. manufacturing & best before date, volume, and price are also printed after filling. Light ingress and oxygen ingress is minimum if the sealing is done properly.

C. Poly Ethylene Terephthalate (PET) Bottles:

Now days the Demand of the carbonated soft drink packed in PET bottles are much higher than the other packing. The PET packing of soft drinks ranges typically from 250 ml to 2.25 litres. These bottles are manufactured in-house in Blow molding machine. The preform having neck finish and threads are heated and expanded to produce the required size and shape. The weight of the preform is approximately 12 Gms to 25 Gms depending on the single serve soft drink volume to be filled.

Philip R Ashurst [3] quoted that "Shelf-life of carbonated drinks in PET is shorter than for products packaged in glass or cans. This is due to the loss of CO_2 through container walls. For a typical 2 Litre PET bottle weighing 43 Gms, a loss of some 15–16% of gas may be expected to occur within 8 weeks of bottling." There is approximately 15% loss of CO_2 from these pet bottles' wall within a period of 6 to 8 weeks, for 250 ml and 2.25 litre bottles respectively. This deterioration of the product increases the oxygen ingress thus reducing shelf life. The Shelf life may be increased by using high cost polymers as replacement of PET. Typical bottling line is shown below in fig. 3

Fig. 3: Bottling Line

Some serious accidents due to explosions have been occurred during closures on carbonated soft drinks, due to high pressure release from the bottles. As a measure present designs have a vertical slot on the closure threads on the bottles. This slot allows initial release for the venting of excess gas pressure thus explosive cap release due to high pressure in the bottle can be avoided.

VII. PACKING AND DISPATCHING

As the bottling of the drink is done at low temperature around 2℃ to 7℃ thus it is necessary to increase the temperature up to room temperature before the final packing of Can and PET bottles. This is done by spraying hot water on the bottles or cans of the soft drinks, and labeling and primary coding is done on the PET bottles. Now these are packed in corrugated boxes or in the shrink wrap, which are secondary coded and dispatched to the market for consumption. And there is no need to heat up the glass bottles up to room temperature and only primary coding is done. Now this is directly put in to the plastic crates and dispatched to the market.

VIII. UTILITIES

The following utilities are required for a bottling plant.

A. Air System:

While processing of the soft drink compressed air is required at many places. Thus the air system is needed to draw the atmospheric air, compress it to required pressure in the air compressor and then filtered air is supplied wherever necessary. Generally low pressure air system is used for filling and packaging of the bottles and for shrink-wrap. The air pressure in this LP system is around 7 to 9 kg/cm^2 gauge. And a High Pressure system having the air pressure as 28 to 32 kg/cm^2 gauge is used for blowing the hot preform to make PET bottles of required shape and size, in Blow Molding Machine. The HP air compressor system used in a medium size bottling plant is shown in fig.4.

Fig. 4: HP Air Compressor System

B. Heating System:

While making the raw syrup treated water is heated by steam (indirect heating) to give hot treatment to Raw Syrup as 80℃. A medium capacity bottling plant requires raw syrup flow approximately as 6000 LPH to 8000 LPH. This requires large amount of thermal energy for getting required temperature of the syrup. Heating is done by the low pressure steam which is generated in Veesons or thermax boiler at 10 Kg/cm^2 g but the heat transfer by steam is carried out at pressure 2.5 Kg/cm^2 g, in Shell & Tube (S&T) or jacketed or Plate heat exchanger (PHE). For this purpose, generally Oil fired boilers or Biomass fired Boilers are used. The boiler is controlled by The Indian Boilers Act, 1923 and the time to time amendments in it. The latest amendment was made in year 2017 and most probably revised act is going to be implemented in current year 2020. The control of flue gases is done under air (prevention and control of pollution) act 1981. The image of typical biomass boiler used in medium size beverages plant is shown in fig5.

Fig. 5: Biomass Boiler

C. Cooling System:

As discussed above the raw syrup is cooled from 80℃ to 40℃ temperature by cold water of the overhead cooling tower. It may require more than one cooling tower (shown in fig.6) which depends upon the requirement of syrup which in turn depends upon the bottling capacity and the production schedule of the ready syrup tanks. The waste heat in the cooling tower may be recovered and utilized for making the Raw syrup for the next batch of the beverage processing.

Further for second stage cooling of the raw syrup 40℃ to around 21℃ and the product cooling of the ready syrup around 2℃ to 7℃ for bottling, a huge capacity refrigeration system is required. For medium capacity bottling generally industrial vapour compression refrigeration system, having ammonia as refrigerant, of capacity 200 to 250 TR is used. The image of a medium size industrial refrigeration system is shown in fig. 7.

All the Heating and cooling systems installation should follow the ASHRAE (American Society of Heating Refrigeration and Air conditioning Engineers) and ISHRAE (Indian society of Heating Refrigeration and Air conditioning Engineers) guidelines.

Fig. 6: Cooling Tower

Gagan Malik [4] concluded "%13-23 heat recovery possible to heating capacity operating under different condition and the increase in temperature of water achieved by 40 deg C". Thus this heat recovery from a refrigeration system is utilized for heating of water for syrup making.

Fig. 7: Industrial Refrigeration System

D. Power:

A Medium size beverages plant requires un-interrupted supply of power of Range 1500 KVA. This requires high level of safety because supply is generally from HT i.e. 33 KV or 11 KV line according to Electricity act 2003 which is proposed amendment in current year 2020. The Electrical installation and safety in the plant is maintained according to Electrical Safety Regulation (ESR) Act 2010, amended in year 2015 of Central Electricity Authority. And Diesel Generator (DG) SET of same capacity for backup power is needed. The control of Exhaust gases from DG is done under air (prevention and control of pollution) act 1981.

E. Effluent Treatment Plant (ETP):

All beverages industries produce effluents in the processes, mainly water. Just to reutilize and sustained the water for housekeeping, gardening etc. or to release it in to the nature it should be treated to ensure that there is not any contaminants in it. There is an act known as water (prevention and control of pollution) act 1974, according to which there should be in-house ETP installed.

IX. CONCLUSION

The above Processing of non alcoholic carbonated drinks gives the scope of research work to be carried out by observation and data collection for the various processes involved in production, its bottling and the utilities of the plant. The following broad areas may be considered.

1) Analysis of Automation of the Bottling line and packaging system of soft drinks.
2) Optimization and waste heat recovery of various processes like compression, condensation, evaporation, cooling towers heat exchange in Industrial Refrigeration plant so that the performance of the system may be improved.
3) Optimization of heating system processes like Steam generation, transportation and utilization.

4) Optimization of air system processes like compressed air generation, transportation and its utilization.
5) Analysis of heat rejection during processing of soft drinks as waste heat and its utilization at other places in the same plant to improve thermal efficiency.
6) Analysis and optimization of the molding machine used for in house production of PET bottles.
7) Plant layout analysis to reduce the material handling.
8) Application of modern management tools like 5 S, TQM, TPM, PIT SPOT, Drive the 5 (DT 5), Manufacturing & Ware-housing (M&W) to improve the productivity.
9) Variation in Quantity of Ingredients and their quantity used which affects the quality of soft drinks.
10) Market trends and potential of consumption of soft drinks.

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