# Introduction

Recent regulatory changes emphasize the importance of having a comprehensive understanding of manufacturing processes and their impact on product quality. At ABC Beverage, pH levels are a critical parameter for ensuring consistency and maintaining product standards. This analysis aims to identify and quantify the factors driving pH variability while developing a predictive model that meets these new regulatory standards. By leveraging advanced analytical methods and predictive modeling techniques, the analysis provides data-driven insights to ensure compliance and enhance understanding of the production process.

The scope of this analysis includes data preprocessing, the identification of predictive factors, and the development and validation of a robust predictive model for pH levels. The focus is on exploring relationships within the manufacturing data to uncover insights that can drive better decision-making. By implementing this structured approach, the findings will provide actionable insights into the key drivers of pH variability and a reliable framework for prediction.

Understanding and predicting pH levels is crucial not only for meeting regulatory standards but also for maintaining operational excellence. Accurate prediction will enable more efficient quality control, reducing variability and ensuring that ABC Beverage consistently delivers high-quality products. The results of this analysis will empower the company to address compliance needs while optimizing its manufacturing process, underscoring the importance of data-driven decision-making in the production environment.

## Dataset Overview

The dataset comprises observations collected from a beverage production line, capturing information about carbonation levels, filling processes, environmental conditions, and quality control metrics. Each row represents a single production instance, and each column corresponds to a specific variable measured or controlled during the process.

```{r}

# Create a dataframe in R

variables <- data.frame(

Feature = c(

"Brand Code", "Carb Volume", "Fill Ounces", "PC Volume", "Carb Pressure",

"Carb Temp", "PSC", "PSC Fill", "PSC CO2", "Mnf Flow", "Carb Pressure1",

"Fill Pressure", "Hyd Pressure1", "Hyd Pressure2", "Hyd Pressure3", "Hyd Pressure4",

"Filler Level", "Filler Speed", "Temperature", "Usage cont", "Carb Flow",

"Density", "MFR", "Balling", "Pressure Vacuum", "PH", "Oxygen Filler",

"Bowl Setpoint", "Pressure Setpoint", "Air Pressure", "Alch Rel", "Carb Rel",

"Balling Lvl"

),

Description = c(

"Unique identifier for the product's brand.",

"Volume of carbon dioxide dissolved in the product.",

"Volume of liquid dispensed into each container.",

"Process control volume for monitoring liquid levels.",

"Pressure level during carbonation.",

"Temperature during carbonation for CO₂ solubility.",

"Process Setpoint Control for maintaining parameter targets.",

"Filling setpoint under controlled conditions.",

"Setpoint for CO₂ levels during carbonation.",

"Manufacturing flow rate for liquid or gas.",

"Secondary carbonation pressure reading.",

"Pressure applied during filling operations.",

"Hydraulic pressure reading 1 for machine operation.",

"Hydraulic pressure reading 2 for machine operation.",

"Hydraulic pressure reading 3 for machine operation.",

"Hydraulic pressure reading 4 for machine operation.",

"Measurement of product level in containers.",

"Speed of the filling machine or process.",

"Temperature of the process environment.",

"Container usage or consumption metrics.",

"Flow rate of CO₂ during carbonation.",

"Density of the product for consistency monitoring.",

"Mass flow rate of the material through the system.",

"Sugar concentration level measured by the Balling scale.",

"Vacuum pressure in the system.",

"Acidity level of the product.",

"Oxygen levels in the filling process.",

"Target setpoint for intermediate container levels.",

"Desired pressure level in the process.",

"Air pressure measurement in the system.",

"Alcohol release or related parameter.",

"Carbonation release or related measurement.",

"Sugar concentration level in the final product."

),

Type = c(

"Categorical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical", "Numerical", "Numerical",

"Numerical", "Numerical", "Numerical"

),

stringsAsFactors = FALSE

)

variables |> kable(caption = "Beverage Manufacture Process Features") |> kable\_styling() |> kable\_classic()

```

The variables play a crucial role in capturing and monitoring various aspects of the production process, directly impacting product quality and operational efficiency:

* Carbonation Variables: These variables (e.g., Carb Volume, Carb Pressure, and Carb Temp) ensure the beverage achieves the desired level of fizziness and retains CO₂ effectively. They are critical for meeting product specifications and customer satisfaction.
* Filling Variables: Variables like Fill Ounces, PC Volume, and Filler Speed ensure accurate and consistent product volume in containers, minimizing waste and maintaining packaging standards.
* Quality Control Metrics: Metrics such as Density, Balling, and PSC monitor the chemical and physical properties of the beverage, including sugar concentration, density, and carbonation, which significantly influence the product's pH balance. Maintaining the appropriate pH ensures flavor stability, microbial safety, and overall product quality.
* Process Control Variables: Variables like PSC CO2 and PSC act as setpoints to maintain optimal operational conditions, reducing variability and enhancing production reliability.

--Optional

### Annotated References

1. Anton Paar Wiki. (n.d.). Carbon Dioxide in Beverages.  
   Retrieved from <https://wiki.anton-paar.com/au-en/carbon-dioxide-in-beverages/>  
   This resource provides an in-depth understanding of the role of carbon dioxide in beverages, including its effect on carbonation, fizziness, and product quality. It directly supports our analysis of variables like Carb Flow and Carb Pressure, which influence carbonation and pH levels.
2. Omega. (n.d.). What is pH?  
   Retrieved from <https://www.omega.com/en-us/resources/what-is-ph>  
   This article explains the concept of pH, its measurement, and its relevance to various industries. It is useful for understanding the chemical principles behind pH variability in beverages and helps contextualize our target variable within the manufacturing process.
3. Emerson. (n.d.). Training Beverage Process Solutions Guide on De-Aeration.  
   Retrieved from <https://www.emerson.com/documents/automation/training-beverage-process-solutions-guide-on-de-aeration-micro-motion-en-63728.pdf>  
   This document focuses on de-aeration processes in beverage production, particularly the removal of dissolved oxygen and its impact on carbonation and quality. It directly relates to variables like Oxygen.Filler and Pressure.Vacuum, providing insights into their operational importance.
4. Jochamp. (n.d.). Carbonated Beverages Manufacturing Process - A Step by Step Guide.  
   Retrieved from <https://jochamp.com/carbonated-beverages-manufacturing-process/>  
   This guide offers a comprehensive overview of the carbonation process in beverage production, including the role of temperature, pressure, and filling speed. It supports our understanding of variables like Temperature, Filler.Speed, and Carb Pressure, helping us interpret their influence on product quality.