Data Article

Exergoeconomic analysis of an industrial beverage mixer system: Process data

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Abstract

Data presented herein refer to the process data obtained from an industrial beverage mixer system. They include both primary and secondary thermodynamic data pertaining to the material stream flow within the system. Data collection was performed during the production process, and calorimetry experiments were performed to obtain the thermal properties of treated H₂O, carbonated H₂O, syrup, beverage, and carbonated beverage. These experiments were performed because the properties of these substances are not readily available in the literature, possibly because of the trade secrets of the manufacturing process. This is the first time a dataset for a beverage manufacturing environment has been generated, and it can help researchers to conduct further studies on related subjects. Therefore, data are supplementary to the study results of the Exergoeconomic Analysis of an Industrial Beverage Mixer System.

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Specifications Table

| Subject               | Mechanical Engineering |
|-----------------------|------------------------|
| Specific subject area | Thermodynamics         |
| Type of data          | Tables                 |
| Acquisition of data   | Method: Measuring material streams in the process |
|                      | Instruments: digital thermometer, digital clamp multimeter, flow meter, refractometer, Carbo QC, temperature gauge, pressure gauge, IKA C2000 basic calorimeter |
| Data format           | Raw, Analyzed          |
| Parameters for data collection | Before data collection, calibration for all measurement indicators was done based on the manufacturer-recommended procedure. |
| Description of data collection | Calorimeter experiments were conducted to obtain the specific heat capacity, enthalpy, and entropy of treated H₂O, carbonated H₂O, syrup, beverage, and carbonated beverage, while during production, the raw data related to the primary thermodynamic properties of each material streams were measured and analyzed. |
| Data source location  | Beverage manufacturing plant, GPS coordinates: 6.601538°N, 3.375092°E |
| Data accessibility    | With the article       |
| Related research article | Authors' names: Chukwuemeka J. Okereke, Olumuyiwa A. Lasode, Idehai O. Ohijeagbon |
|                       | Title: Exergoeconomic Analysis of Industrial Beverage Mixer System |
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Value of the data

- These data are unique; this is the first time raw data from a beverage manufacturing environment have been documented for research purposes.
- These data reveal insights that can improve the performance of the industrial beverage mixer.
- These data can be useful to researchers working in the field of exergy analysis for further evaluation of industrial beverage mixer systems using different exergoeconomics approaches.
- Researchers will find the thermal properties of treated H₂O, carbonated H₂O, syrup, beverage, and carbonated beverage presented useful in further research related to processing, storage, and preservation of beverages.

1. Data description

Data presented in this article were obtained from a beverage manufacturing plant. A well-illustrated figure and detailed description of the industrial beverage mixer are presented by Okereke et al. [1]. Primary thermodynamic data such as temperature and pressure of the material streams flowing into the mixer were recorded directly using measurement indicators integrated into or mounted on the pipelines, such as thermometers and pressure gauges, respectively. T-thermocouple digital thermometers were used for temperature measurements at points where instruments were not installed on the operating units. The mass flow rates of the material streams apart from NH₃ and air were measured using flow meters. The accuracy of these measurement indicators and other tools used in data acquisition are presented in the calibration and measurement tool accuracy section of this article (Table 5). The mass flow rates of NH₃ and air were calculated based on the work of Okereke et al. [2] and using the engineering toolbox [3], respectively. The built-in sensors in the mixer include sensors for gauging flow, pressure, and temperature, and the readings were obtained through the equipment’s human–machine interface. The secondary thermodynamic data of the material streams through the mixer, such as enthalpy, entropy, and heat capacity of the processing fluids, i.e., NH₃, CO₂, and air, were determined using thermodynamic tables [4–6]. These tables are based on the values obtained for the primary measured data; interpolations were performed where necessary. Secondary data for treated H₂O, carbonated H₂O, syrup, beverage, and carbonated beverage were deduced from a
Table 1
Data obtained from the calorimetry experiments.

| Material stream   | Calorific value (cal/g) | Reference temperature (K) | Temperature rise (K) | Calorimeter constant (cal/K) |
|-------------------|-------------------------|---------------------------|----------------------|-----------------------------|
| Treated H₂O       | 1162.00                 | 298.06                    | 0.2196               | 1242.00                     |
| Carbonated H₂O    | 738.00                  | 298.20                    | 0.1356               | 1242.00                     |
| Syrup             | 672.00                  | 297.88                    | 0.1584               | 1242.00                     |
| Beverage          | 624.00                  | 298.14                    | 0.1486               | 1242.00                     |
| Carbonated beverage | 599.00            | 297.97                    | 0.1436               | 1242.00                     |

Table 2
Data obtained from Brix and gas volume measurements.

| Material stream        | Brix value (°) | CO₂ gas volume (mL) |
|------------------------|----------------|---------------------|
| Syrup                  | 52.29          |                     |
| Beverage               | 10.62          |                     |
| Carbonated beverage    | 10.62          |                     |
| Carbonated H₂O         |                | 0.52                |
| Carbonated beverage    |                | 3.6                 |

Table 3
Electrical data for power apparatus in the mixer system.

| Apparatus             | Current (I) | Voltage (V) | Power (kW) |
|-----------------------|-------------|-------------|------------|
| Treated H₂O pump      | 9           | 380         | 4.74       |
| Syrup pump             | 9.5         | 374         | 4.92       |
| Flow mix pump          | 14          | 370         | 7.18       |
| Air compressor         | 70          | 371         | 35.99      |
| NH₃ compressor         | 167         | 370         | 85.62      |

calorimetry experiment. Their properties have not been revealed in the literature on the account of them being trade secrets. The calorimetry experiment data are summarized in Table 1.

The net calorific value, \( h_{\text{ref}} \), specific heat capacity, \( c_p \), enthalpy, and entropy were obtained using Eqs. (1)–(4), respectively. The samples contained 11.11% hydrogen (H%). [7,2]

\[
h_{\text{ref}} = \text{calorific value} - (0.09 \times \text{H}\% \times 587) \text{cal/g} \quad [7] \\
c_p = \left[ \frac{-K\Delta T}{\Delta T(\degree C)} \right] \times 4.18 \text{ kJ/kg K} \quad [2] \\
h = h_{\text{ref}} + c_p(T - T_{\text{ref}}) \text{ kJ/kg} \quad [2] \\
s = c_p \ln \left( \frac{T}{273.15} \right) \text{ kJ/kg K} \quad [2]
\]

where \( h_{\text{ref}} \) (cal/g) is the net calorific value, H% is the percentage of hydrogen in a sample, \( K \) (cal/K) is the calorimeter constant, \( \Delta T \) (K) is the temperature rise, \( T_{\text{ref}} \) (K) is the temperature of the sample in the reference state, \( T \) (K) is the temperature stream during production, \( h \) (kJ/kg) is the enthalpy, \( s \) (kJ/kgK) is the entropy, and \( C_p \) (kJ/kgK) is the specific heat capacity.

The Brix of the syrup and beverage was measured with a refractometer, while the gas volume in the carbonated H₂O and beverage was determined by a CarboQC meter. The results are presented in Table 2.

The voltage and current of the power input to the treated H₂O pump, syrup pump, flow mix pump, NH₃ compressor, and air compressor were measured using a digital clamp meter. The power consumption was obtained from Eq. (5). The electrical data obtained are presented in Table 3, and a summary of the thermodynamic data of the industrial beverage mixer system is
Table 4
Thermodynamic data of the industrial beverage mixer system.

| State        | Material stream | Mass flow rate (kg/s) | Temperature (°C) | Pressure (bar) | Enthalpy (kJ/kg) | Entropy (kJ/kgK) |
|--------------|-----------------|-----------------------|------------------|----------------|------------------|------------------|
| 1            | Treated H₂O     | 2.50                  | 27.00            | 1.70           | 2412.48          | 0.39374          |
| 2            | Treated H₂O     | 0.23                  | 27.43            | 4.00           | 2414.27          | 0.39972          |
| 3            | Treated H₂O     | 2.27                  | 27.43            | 4.00           | 2414.27          | 0.39972          |
| 4            | Air             | 0.01                  | 27.00            | 3.50           | 300.06           | 6.58186          |
| 5            | Treated H₂O     | 2.27                  | 27.50            | 4.00           | 2414.56          | 0.40069          |
| 6            | CO₂             | 0.01                  | 18.00            | 1.20           | 411.76           | 1.72440          |
| 7            | Air             | 0.01                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 8            | Carbonated H₂O  | 2.27                  | 28.00            | 3.89           | 639.03           | 0.25163          |
| 9            | Carbonated H₂O  | 2.27                  | 28.00            | 3.89           | 639.03           | 0.25163          |
| 10           | Syrup           | 0.53                  | 28.00            | 1.00           | 365.40           | 0.29397          |
| 11           | Syrup           | 0.53                  | 30.00            | 5.00           | 371.42           | 0.31391          |
| 12           | Air             | 0.01                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 13           | Syrup           | 0.53                  | 31.00            | 5.00           | 374.43           | 0.32383          |
| 14           | Air             | 0.01                  | 29.00            | 5.00           | 302.15           | 6.58834          |
| 15           | Syrup           | 0.53                  | 32.00            | 5.00           | 377.45           | 0.33371          |
| 16           | Syrup           | 0.53                  | 32.00            | 5.00           | 377.45           | 0.33371          |
| 17           | Air             | 0.01                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 18           | Air             | 0.01                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 19           | Beverage        | 2.80                  | 29.50            | 1.10           | 167.65           | 0.28981          |
| 20           | Beverage        | 2.80                  | 31.50            | 4.20           | 173.30           | 0.30842          |
| 21           | CO₂             | 0.02                  | 28.00            | 10.00          | 381.20           | 1.59990          |
| 22           | CO₂             | 0.02                  | 28.00            | 3.40           | 381.20           | 1.59990          |
| 23           | Beverage        | 2.80                  | 28.00            | 5.00           | 163.41           | 0.27577          |
| 24           | Air             | 0.02                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 25           | Beverage        | 2.80                  | 29.40            | 5.00           | 167.37           | 0.28888          |
| 26           | CO₂             | 0.13                  | 27.00            | 10.80          | 386.39           | 1.61890          |
| 27           | CO₂             | 0.10                  | 18.00            | 2.50           | 411.76           | 1.72440          |
| 28           | NH₃             | 0.18                  | 126.64           | 14.50          | 1717.78          | 5.82151          |
| 29           | NH₃             | 0.18                  | −10.00           | 2.60           | 1450.20          | 5.75500          |
| 30           | Carbonated beverage | 2.82              | 10.00            | 4.20           | 17.53            | 0.07992          |
| 31           | Air             | 0.01                  | 29.00            | 3.50           | 302.15           | 6.58834          |
| 32           | CO₂             | 0.03                  | 29.00            | 1.10           | 411.76           | 1.72440          |
| 33           | Air             | 0.16                  | 26.00            | 1.00           | 299.15           | 6.85769          |
| 34           | Air             | 0.16                  | 30.00            | 7.00           | 303.15           | 3.36730          |
| 35           | Air             | 0.07                  | 29.00            | 6.80           | 302.15           | 6.34100          |
| 36           | Air             | 0.08                  | 29.00            | 6.80           | 302.15           | 6.34100          |
| 37           | CO₂             | 0.23                  | 28.00            | 12.00          | 381.20           | 1.59990          |

presented in Table 4 [8].

\[
W = \text{voltage} \times \sqrt{3} \times \text{powerfactor} \quad [8]
\]  
(5)

2. Experimental design, materials, and methods

A brief explanation of the data acquisition methods and experiments is given below:

1. Temperature measurement: A temperature gauge, digital thermometer, and temperature sensors were inserted into the material streams at various locations, to record the measured data.

2. Pressure measurement: A pressure gauge and pressure sensors were inserted into the material streams at various locations, and the data were measured and recorded.

3. Voltage and current measurement: For the power apparatus, a digital clamp multimeter was used, and the current and voltage measurements were recorded.

4. Mass flow rate measurement: The mass flow measurements were derived from the volume flow measurements of the flow meters and sensors. The volume flow rate was recorded from the flow meters and flow sensors.
Table 5
Measurement tool specifications.

| Instruments          | Manufacturer                        | Accuracy                                      |
|----------------------|-------------------------------------|-----------------------------------------------|
| Digital thermometer  | Omega Engineering Inc, USA          | ±1%                                           |
| Digital clamp multimeter | Mastech Group, India              | ±0.05%                                       |
| Refractometer        | Anton Paar GmbH, Austria           | ±0.01                                         |
| Carbo QC             | Anton Paar GmbH, Austria, India    | ±0.01%                                       |
| Temperature gauge    | Tempsens Instruments Pvt. Ltd., India | ±1.0%                                       |
| Pressure gauge       | ITEC, Italy, Micro Process Controls, Italy and WIKA, Germany | ±1.0%, ±1.0% for ITEC, Italy; ±1.0% for Micro Process Controls, India; ±1.0% for WIKA |
| Flow meters          | Endress+Hauser AG, Switzerland, Flow meters, USA | ±1%; ±1% for flow metrics: ±1% |
| IKA C2000 basic calorimeter | IKA-Werke GmbH & Co. KG, Germany | <0.2%                                        |

5. Brix measurement: These measurements were performed using a refractometer by cleaning the refractometer lens with distilled H₂O and then dropping the solution sample on the lens. The Brix value was subsequently displayed.

6. Gas volume measurement: Carbo QC was used to measure the gas volume of the beverage and carbonated H₂O by equilibrating a sealed bottle containing the sample for approximately 1 min. The equilibrated sample bottle was then placed in the measurement chamber of Carbo QC. The measured data were displayed approximately 90 s after the machine was turned on.

7. Calorimetry experiment: An IKA C2000 basic calorimeter was used to determine the energy values of the treated H₂O, syrup, beverage, and carbonated beverage. The installation of the machine involved selecting the machine operation mode, isoperibolic, based on the cooling temperature. The machine was then configured based on the sample details, time, language, measuring parameters, and units, followed by calibrating the machine based on the procedure recommended by the manufacturer. The sample was measured in a decomposition vessel, which was placed inside the measurement cell that closes automatically during operation. The sample was combusted in a measurement cell. The combustion process was initiated by an ignition spark and was sustained with the aid of oxygen from an oxygen filling apparatus. The temperature of the process was controlled by H₂O in the inner vessel, which was stirred to ensure uniform heat distribution. The calorimeter measured all parameters related to the sample.

3. Calibration and measurement tool accuracy

All instruments were calibrated based on manufacturer-recommended procedures. The details regarding the manufacturer and the accuracy of each measuring instrument are presented in Table 5.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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