ABSTRACT

In the present work, two different geometries of spargers for beverage carbonation were modelled by means of CFD technique. The first geometry presented a radial inlet of liquid food while the second one a tangential one. Calculation allowed to identify the best solution and mathematical results were confirmed by experimental tests with both water and apple juice. CFD resulted a very useful technique for in-silico designing not only for simple parts of plants but also for very complicated ones such as carbon dioxide spargers in which gas and liquid interact together.

Keywords: carbonated beverage, computational fluid dynamic, dense phase carbon dioxide,

2. MATERIALS AND METHODS

Two sparger geometries were studied and modelled by means of computational fluid dynamics technique. The modelled sparger geometries were firstly drawn by means of SolidWorks 2013 and then 3D simulated by means of ANSYS 14 software with Boussinesq’s approximation that uses a constant density for both fluids but considers gravity acceleration as a function of expansiveness and temperature of fluids. Sparger for carbonation presented a diameter of 64 mm and an height of 203 mm. the two geometries are reported in figure 1.

![Sparger 1](image1.png)  
![Sparger 2](image2.png)

Figure 1: Radial (Sparger 1) and tangential (Sparger 2) sparger geometries
Flow rate of the food liquid was set at 16 L/h while carbon dioxide at 5.6 L/h. The incoming fluid was considered water while carbon dioxide was considered as the gas. Properties of fluids are reported in the following Table 1:

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar mass [kgmol⁻¹]</td>
<td>44.01</td>
<td>18.02</td>
</tr>
<tr>
<td>Density [kgm⁻³]</td>
<td>1.977</td>
<td>997</td>
</tr>
<tr>
<td>Dynamic viscosity [mWm⁻¹K⁻¹]</td>
<td>0.0149</td>
<td>0.8899</td>
</tr>
<tr>
<td>Thermal expansivity [K⁻¹]</td>
<td>0.00366</td>
<td>0.000257</td>
</tr>
</tbody>
</table>

After modelling, water carbonation was experimentally tested on a pilot plant developed by Valfor srl and located in University of Parma laboratories. The pilot plant presented a total volume of about 2 L and a flow rate varying from 10 to 40 L/h. The equipment could work up to 200 bar and presented several water baths to have constant temperature both of carbon dioxide and product to be carbonated.

The carbonation evaluation was performed by means of image analysis: on the pipeline of the pilot three inspection units as reported in Figure 2 made of transparent polycarbonate were added. By means of a camera images of carbonated water were obtained and dimensions of gas bubbles were measured.

![Figure 2: Inspection unit for bubble measurement](image)

### 3. RESULTS AND DISCUSSIONS

As shown in Figure 3, tangential connection (Sparger 2) seemed to give a better mixing of gas and liquid at the outlet of the sparger.

![Figure 3: CO₂ volume fraction distribution in the outlet section](image)

On the contrary, in Sparger 1, fluid streamlines were present with less homogeneous dispersion at the outlet of the sparger.

In Figure 4, sections of both spargers are reported: as previously observed Sparger 1 presented streamlines with a less homogeneous mixing efficacy.

![Figure 4: Radial (Sparger 1) and tangential (Sparger 2) sparger geometries results of modelling](image)

As it’s possible to see the housing for the sparger was the same while the angle of the inlet flux changed. The gas entered from the basis in the central channel and the liquid food from the lateral connection. Thus, mixing results depended only on fluid flow and relative movements between liquid and CO₂.

In order to quantify mixing efficacy, CO₂ volume on the radius of the outlet of the sparger was calculated and reported in Figure 5.

![Figure 5: CO₂ volume fraction distribution in the outlet section](image)

Data confirmed what previously observed: Sparger 2 gave a more homogenous distribution but unfortunately gave also a lower mean CO₂ volume fraction with a worse mixing effect. In Sparger 2 a great part of gas exited near the wall of the pipe without an actual dissolution into the liquid.

Picture of inspection element (Figure 6) confirmed the presence of gas bubble near the wall in Sparger 2 that were not mixed with liquid.
Figure 6: Bubbles inside the inspection unit

Also from experimental tests Sparger 1 gave better results with a better mixing between water and CO\textsubscript{2} and a more stable carbonated water, as consequence. Thus tangential inlet was not the best solution even if the liquid generated itself turbulence inside the housing and prevented fluid streamlines formation. Probably, turbulence inside the Sparger 2 and the spiral flux on the filter limited the spilling of CO\textsubscript{2}.

4. CONCLUSIONS
In conclusion, this work demonstrated the effectiveness of mathematical model to predict fluid mixing also in complex systems and the usefulness of these models for designing and optimizing also gas sparging systems for the beverage industry.

REFERENCES

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