Maximization of the Performance Ratio of Osmotic Dehydration of Mango Cubes


Abstract. The concentration gradients resulting from dipping fruits in a hyperconcentrated solution cause the fruit to lose water and gain solids. The solid gain results in undesirable sensory changes. The aim of this work was to maximize the performance ratio (PR, defined as the ratio of water loss to solid gain) of osmotic dehydration of mango cubes. Two experiments were carried out, by using non-coated (A) and alginate-coated (B) mango cubes. Each experiment was performed according to a central composite design, varying temperature (30-50°C) and concentration of osmotic solution (50-70°Brix). Maximum PR was predicted to occur under the following conditions: 46°C, 65.5° Brix, for A; 44°C, 65.5° Brix, for B. The PR values of 5.16 and 9.51 were observed, respectively, for A and B under such conditions. The alginate coating increased water loss and reduced solid gain, enhancing the PR of the process.

Osmotic dehydration, a technique adequate to produce high moisture fruits, involves immersing fruit pieces in a hypertonic solution. The main objective of the process is the water loss, although a solid gain occurs also, promoting sensory changes in the product (Azoubel & Murr, 2000). So, a maximum dehydration combined with minimum sensory changes may be obtained by maximizing the performance ratio (PR), defined by Camirand et al. (1992) as the ratio of water loss to solid gain. Some process variables affect water loss and solid gain. A temperature increase favors the dehydration kinetics (Lenart & Lewicki, 1990); however, temperatures higher than 50°C may promote browning and flavor deterioration (Videv et al., 1990). The mass transfer, particularly water loss, is also affected by concentration of osmotic solution (Rahman & Lamb, 1990). According to Camirand et al. (1992), the PR of the process may be enhanced by a hydrophilic edible coating, which favors water loss but reduces solid gain, such as calcium alginate obtained from sodium alginate cross-linked with calcium ions. The objective of this work was to evaluate the effects of temperature, concentration of osmotic solution and an alginate coating on mass transfer during osmotic dehydration of mango cubes, as well as to maximize the performance ratio of the process.

Materials and Methods

‘Tommy Atkins’ mangoes were obtained in the local market in Fortaleza, CE, Brasil. The osmotic agent was sucrose. The coating was formed from sodium alginate (provided by Danisco Ingredients Brasil, Embu, SP) and calcium chloride. The fruits were washed, sanitized, peeled, cut in cubes and sequentially dipped in a 1.5% sodium alginate solution (30 s) and a 2.4% calcium chloride solution (60 s). The cubes were then transferred to erlenmeyers containing the sucrose solution, in a

Table 1. Coded and uncoded levels of the independent variables for osmotic dehydration of both non-coated and alginate-coated mango cubes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Temperature (°C)</th>
<th>Solution concentration (% oBrix)</th>
<th>Temperature (°C)</th>
<th>Solution concentration (% oBrix)</th>
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</thead>
<tbody>
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<td>A</td>
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<td>1</td>
<td>33</td>
<td>53</td>
</tr>
<tr>
<td>B</td>
<td>-1</td>
<td>1</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>C</td>
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<td>1</td>
<td>33</td>
<td>67</td>
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<tr>
<td>D</td>
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<tr>
<td>E</td>
<td>1.41</td>
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<td>F</td>
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<td>-1.41</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>G</td>
<td>0</td>
<td>1.41</td>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
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<td>40</td>
<td>60</td>
</tr>
<tr>
<td>J</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>60</td>
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</tbody>
</table>

Table 2. Responses resulting from osmotic dehydration of non-coated (experiment A) and alginate-coated (experiment B) mango cubes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>WR (%</th>
<th>WL (%)</th>
<th>SG (%)</th>
<th>PR</th>
<th>WR (%)</th>
<th>WL (%)</th>
<th>SG (%)</th>
<th>PR</th>
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<td>B</td>
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<td>41.87</td>
<td>11.68</td>
<td>3.58</td>
<td>38.57</td>
<td>48.57</td>
<td>10.01</td>
<td>5.32</td>
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<td>C</td>
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<td>37.38</td>
<td>11.25</td>
<td>3.34</td>
<td>34.25</td>
<td>43.88</td>
<td>9.63</td>
<td>4.57</td>
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<tr>
<td>D</td>
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<td>48.94</td>
<td>9.81</td>
<td>5.02</td>
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<td>55.01</td>
<td>6.52</td>
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<td>E</td>
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<td>F</td>
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<td>45.64</td>
<td>8.73</td>
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<td>51.63</td>
<td>6.54</td>
<td>7.98</td>
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<tr>
<td>G</td>
<td>24.49</td>
<td>36.12</td>
<td>11.63</td>
<td>3.14</td>
<td>32.26</td>
<td>40.02</td>
<td>7.77</td>
<td>5.16</td>
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<td>H</td>
<td>35.03</td>
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<td>8.63</td>
<td>5.09</td>
<td>43.19</td>
<td>48.02</td>
<td>4.83</td>
<td>10.10</td>
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<td>I</td>
<td>33.81</td>
<td>42.14</td>
<td>8.33</td>
<td>5.16</td>
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<td>48.77</td>
<td>5.74</td>
<td>8.60</td>
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<td>42.05</td>
<td>7.79</td>
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<td>K</td>
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<td>36.88</td>
<td>9.32</td>
<td>3.98</td>
<td>39.46</td>
<td>45.67</td>
<td>6.21</td>
<td>7.39</td>
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</table>
weight ratio of 1:5 (mango cubes: solution). The osmotic dehydration was carried out with stirring at 110 rpm in a temperature-controlled shaker for 2 hours. After the process, the osmotic solution was drained in a sieve for 2 minutes. In order to evaluate the effects of the coating, a control was run in which the cubes were not alginate coated. The experiments were called A (non-coated cubes) and B (coated cubes). Each experiment was made according to a central composite design, with temperature and concentration of osmotic solution as the independent variables. Except for the presence or absence of the coating, the conditions of both the treatments were identical. Table 1 presents the coded and uncoded levels of the variables in each treatment. The responses (dependent variables) were defined as: percent weight reduction (WR), percent water loss (WL), percent solid gain (SG), and performance ratio (PR = WL/SG). WL and SG were based on the initial mass of the material.

The results were analyzed by Response Surface Methodology, by using the software Statistica (Statsoft, 1995). The maximization of PR was carried out by determining the stationary point of the surface referring to this response (Cornell, 1990). The conditions that provided the maximum PR were considered as “optimal”. In a subsequent step, both the experiments were performed in a pilot-scale under the optimal conditions, in order to compare predicted and observed values. The effect of the alginate coating on the process was evaluated by comparing means of the responses obtained from the experiments by t-tests.

Results and Discussion

The responses obtained from the experiments A and B are presented in Table 2, and the regression coefficients of the coded models in Table 3. The most reliable models were those referring to WR and WL. The models referring to SG and PR of experiment B were not significant (p ≤ 0.05). According to the models, both temperature and solution concentration affected positively weight reduction and water losses, and negatively the solid gain. The positive effects of both variables on weight and water losses confirm results reported by other authors (Beristain et al., 1990; Heng et al., 1990; Lenart & Lewicki, 1990; Fernandez et al., 1995). On the other hand, their negative effects on solid gain differed from the observations by those authors.

Table 4 presents the comparison of means between experiments, which were significantly different (p ≤ 0.05) for all responses. The alginate coating increased water loss and decreased solid gain, enhancing then the performance ratio. Figure 1 indicates the noticeable increases in performance ratio promoted by the coating. Such results are in accordance with those described by Azeredo & Jardine (2000) for pineapple pieces. The maximum PR of experiment A (PR = 5.43) was predicted to occur at 46°C with a 65.5° Brix solution. For experiment B, the optimal conditions (PR = 9.62) were predicted to be: temperature, 44°C; solution concentration, 65.5° Brix. Although some models were not regarded as reliable, a good approximation between observed and predicted values has been obtained for all responses under the optimal conditions (Table 5).

![Figure 1. Contour plots of the performance ratios of osmotic dehydration of non-coated (experiment A) and alginate-coated (experiment B) mango cubes.](image-url)
Table 4. Comparison of means of the responses obtained from osmotic dehydration of non-coated (experiment A) and alginate-coated (experiment B) mango cubes.

<table>
<thead>
<tr>
<th>Responses</th>
<th>Means</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experiment A</td>
<td>Experiment B</td>
<td>t</td>
<td>P</td>
<td></td>
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<tr>
<td>WR*</td>
<td>29.9507</td>
<td>38.7574</td>
<td>-3.1498</td>
<td>0.0050</td>
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<tr>
<td>WL*</td>
<td>40.0326</td>
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<tr>
<td>SG*</td>
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<td>3.8695</td>
<td>0.0009</td>
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<tr>
<td>PR*</td>
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<td>7.0746</td>
<td>-3.8824</td>
<td>0.0009</td>
<td></td>
</tr>
</tbody>
</table>

*Responses for which the experiments A and B were different (p ≤ 0.05).


WR(%): weight reduction; WL(%): water loss; SG(%): solid gain; PR: performance ratio.

Table 5. Responses under the model-predicted optimal conditions of osmotic dehydration of non-coated (experiment A) and alginate-coated (experiment B) mango cubes.

<table>
<thead>
<tr>
<th>Responses</th>
<th>Experiment A</th>
<th>Experiment B</th>
<th>Predicted</th>
<th>Observed</th>
<th>Predict</th>
<th>Observed</th>
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<tbody>
<tr>
<td>Weight reduction (%)</td>
<td>38.34</td>
<td>33.94</td>
<td>46.14</td>
<td>43.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water loss (%)</td>
<td>46.87</td>
<td>42.19</td>
<td>51.35</td>
<td>48.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid gain (%)</td>
<td>8.53</td>
<td>8.26</td>
<td>5.21</td>
<td>5.10</td>
<td></td>
<td></td>
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<tr>
<td>Performance ratio</td>
<td>5.43</td>
<td>5.16</td>
<td>9.62</td>
<td>9.51</td>
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Literature cited


