Soy milk effect on antioxidant activity of tea and coffee

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Abstract. Numerous studies have demonstrated the effect of cow's milk on the antioxidant properties of tea and coffee, which has been largely attributed to the interaction between milk proteins and plant polyphenols. In this work, we applied redox potentiometry using potassium hexacyanoferrates in assessing the antioxidant activity (AOA) of beverages prepared by adding soy milk to tea or coffee. The AOA of the drinks was calculated with adjustments for volume fraction and AOA of soy milk. Addition of 10–30% (v/v) soy milk to green tea, black tea, drip coffee and lungo had no effect on the AOA of the original drinks, and the recorded deviations were within ± 4%. Cappuccino made with 67% (v/v) foamed soy milk showed a 24% increase in AOA compared to espresso.

1 Introduction

Tea [1] and coffee [2] are popular soft drinks consumed by people of different age groups all over the world. Experimental and epidemiological studies have demonstrated that polyphenolic compounds in tea and coffee exhibit antioxidant, anti-inflammatory, antimicrobial, anticancer, antidiabetic, neuroprotective, and other bioactive effects. This allows tea and coffee to be classified as functional drinks commonly used for the prevention of severe and common diseases. The use of tea and coffee in combination with milk is determined by taste preferences and/or national traditions. In some cases, the interaction of polyphenolic compounds with milk proteins can lead to a decrease in the antioxidant activity (AOA) of these drinks. For example, using redox potentiometry using potassium hexacyanoferrates ($\text{K}_3[\text{Fe(CN)}_6]/\text{K}_4[\text{Fe(CN)}_6]$), it was shown that adding cow's milk to coffee is accompanied by a decrease in the AOA of the latter [3]. It should be noted that the literature data on the effect of milk on the antioxidant properties of tea [4] and coffee [5] are quite contradictory. The observed discrepancies in results have led to debate in the scientific community and have been attributed to the influence of various factors, including the type of tea or coffee, the type and amount of milk added, the method of preparation of the drink, and the method of analysis used.

Recently, grain-, legume- or nut-based beverages have been introduced into the food market and have been referred to as plant milk, alternative milk, milk replacers or even milk analogues for commercial and marketing purposes [6–11]. These drinks are suspensions of plant materials in water and resemble cow's milk in appearance. Its
nutritional and functional properties depend on the plant material used, processing and fortification. Plant milk is recommended for vegetarians and people suffering from lactose intolerance, cow's milk allergy and hypercholesterolemia. Data on the short- and long-term health effects of plant-based milk substitutes on human health are scarce [7], and their organoleptic acceptability may be limited [6, 7, 12] and ambiguous [13].

While the effects of cow's milk on the antioxidant properties of tea and coffee have been extensively studied [4, 5], similar studies involving plant milk are underrepresented. In the study [14] spectrophotometric methods have been employed to show that adding 20% (v/v) soy, rice and almond milk to 'English breakfast' tea does not significantly affect the total polyphenol content and the antioxidant capacity of the tea infusion. In this work, we investigated the effect of soy milk on the AOA of tea and coffee in order to assess the possible effect on the functional properties of drinks.

2 Research methodology

Chemical reagents K$_3$[Fe(CN)$_6$], K$_4$[Fe(CN)$_6$]·3H$_2$O, KCl, NaCl, Na$_2$HPO$_4$·12H$_2$O and KH$_2$PO$_4$ of "chemically pure" qualification were obtained from Chemreaktivsnab JSC (Russia). Greenfield Flying Dragon large-leaf green long tea, Greenfield Golden Ceylon large-leaf black long tea, Jockey Classic medium-roast Arabica coffee beans (Orimi LLC, Russia) and Zdorovoe menu soy milk (Soyuzpichsheprom LLC, Russia) were purchased from a retail chain.

In preparing the reagent solution and drinks, deionized water was used which was obtained at the installation Akvalab-UVOI-MF-1812 (RPC Mediana-Filter JSC, Russia).

Green/black tea was prepared in the following way: 2 g of long leaf tea was placed in a ceramic container, 100 ml of water heated to 80/95 °C was added, infused for 1/5 minute(s) and filtered through a sieve. To prepare coffee drinks, coffee beans were ground in a KT-1329 rotary coffee grinder (Kitfort LLC, Russia). Drip coffee was prepared manually: 6 g of ground coffee was poured into a filter installed in a funnel and then 100 ml of water heated to 95 °C was gradually added. Espresso, lungo and cappuccino were prepared using a Mystery MC-B-5120 coffee machine (Mystery Electronics Pte Limited, China). To do this, 6 g of ground coffee was poured into the coffee maker holder, leveled and pressed using a tamper. The resulting tablet was passed through heated water in an amount of 30 ml for espresso and 100 ml for lungo under pressure. The cappuccino was made by adding warm and frothed soy milk to espresso at 67% by volume. Before measuring AOA, the resulting drinks were cooled in a water bath to room temperature.

The determination of AOA was carried out by the potentiometric method using a redox couple K$_3$[Fe(CN)$_6$]/K$_4$[Fe(CN)$_6$]. 1 ml of the drink being analyzed was added to 10 ml of phosphate buffered saline pH 7.4 containing 10 mM K$_3$[Fe(CN)$_6$] and 0.1 mM K$_4$[Fe(CN)$_6$]. To avoid possible interference, an 11-fold sample dilution was used in the analysis [16]. Measurements of potential before and after sample introduction were recorded in an electrochemical cell consisting of platinum electrode 6.1204.310 with disk diameter 3 mm (Metrohm AG, Switzerland), silver chloride reference electrode EVL1M3.1 (Gomel Plant of Measuring Devices JSC, Belarus) and DPTA.25.0220.000SB thermal sensor (RPE Tomanalyt LLC, Russia). In the measurements pH/ions meter TA-Ion (RPE Tomanalyt LLC, Russia) was used.

AOA of drinks in mmol-eq/L (mM-eq) was calculated taking into account the following corrections:

\[
AOA_{\text{beverage}} = \frac{AOA_s - w \cdot AOA_{sm}}{w}
\]
In the formula:

\[ \text{AOA}_s \]

is the AOA of a sample obtained by mixing tea or coffee with a certain volume of soy milk; \( w \) is the volume fraction of soy milk in the sample; \( \text{AOA}_m \) is the AOA of soy milk.

Measurements were performed in triplicate (n = 3). The results obtained are presented as the arithmetic mean with the corresponding standard deviation. Statistical analysis was performed using PSPP for Microsoft Windows (Free Software Foundation Inc., USA).

3 Results and discussion

Soy milk had AOA, which was consistent with literature data [17] and required adjustments in the calculations. Processing soy milk in a cappuccino maker led to a slight decrease in AOA (Fig. 1): 0.56 ± 0.03 mM -eq versus 0.52 ± 0.05 mM -eq (\( p = 0.074 \)).

The results obtained are explained by a slight dilution of soy milk with water vapor and, possibly, partial destruction of heat-labile antioxidants. The corresponding AOA values of soy milk were taken into account in the calculations of the AOA of drinks using the formula (1).

\[ \text{AOA} \]

Fig. 1. AOA of not frothed and frothed (foamed) soy milk (n = 3).

The results of determining the AOA of drinks are presented in Table 1. The AOA of green tea exceeds the AOA of black tea by an average of 11.6%, which is consistent with the literature data [1]. Unfermented green tea and fully fermented black tea are derived from the leaves of the Camellia sinensis plant. During the fermentation process, phenoloxidases catalyze the oxidation of polyphenolic compounds with atmospheric oxygen, which leads to a decrease in the AOA of fermented teas compared to unfermented ones. The AOA of lungo exceeds the AOA of drip coffee by an average of 30.3%, which is associated with an increase in the yield of extra-active antioxidant substances. Preparing lungo in a coffee maker involves the use of temperature and pressure, which affect the completeness and speed of antioxidant extraction, while preparing drip coffee by hand involves only temperature. It is evident from Table 1 that adding 10–30% (v/v) soy milk to green tea, black tea, drip coffee and espresso does not have a significant effect on the AOA of the original drinks (\( p > 0.05 \)), and the recorded deviations are within ± 4%. When preparing cappuccino, adding 67% foamed soy milk to espresso led to a statistically significant (\( p < 0.05 \)) increase in the AOA of the latter, which in percentage terms was [2024].
Table 1. AOA of drinks

<table>
<thead>
<tr>
<th>Beverage</th>
<th>Added soy milk, % vol.</th>
<th>AOA, mM-eq</th>
<th>Deviation, %</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green tea</td>
<td>0</td>
<td>14.25</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>14.34</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>14.41</td>
<td>0.61</td>
<td></td>
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<td></td>
<td>30</td>
<td>14.43</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Black tea</td>
<td>0</td>
<td>12.60</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>12.54</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>12.30</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>12.84</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Drip coffee</td>
<td>0</td>
<td>26.60</td>
<td>1.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>27.57</td>
<td>1.88</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>27.41</td>
<td>2.03</td>
<td></td>
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<tr>
<td></td>
<td>30</td>
<td>27.66</td>
<td>2.65</td>
<td></td>
</tr>
<tr>
<td>Lungo</td>
<td>0</td>
<td>38.19</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>36.80</td>
<td>2.28</td>
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<td>37.41</td>
<td>2.36</td>
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<td></td>
<td>30</td>
<td>38.78</td>
<td>2.65</td>
<td></td>
</tr>
<tr>
<td>Espresso</td>
<td>0</td>
<td>67.83</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>62.83</td>
<td>77.93</td>
<td>3.05</td>
<td></td>
</tr>
</tbody>
</table>

Note: The asterisk indicates the volume fraction of frothed (foamed) soy milk.

4 Conclusion

Nutritional support is a new achievement in nutritional science aimed at preserving health and preventing nutrition-related diseases. Tea and coffee are the most commonly consumed functional drinks and are characterized by beneficial therapeutic effects aimed at maintaining health and reducing the risk of disease. However, the addition of cow's milk to tea or coffee may be characterized by a decrease in AOA and, as a result, a deterioration in the functional orientation of the drinks. Recently, plant-based milk substitutes have appeared in the food market, the study of which still requires the participation of scientists.

This work showed that adding native soy milk to tea or coffee has no effect on the AOA of drinks, while adding foamed soy milk to coffee even increases the AOA of the latter. Apparently, foaming can lead to changes in the properties of plant milk, but the underlying mechanism requires further study.

References

5. https://doi.org/10.1051/e3sconf/202453710009


