Effect of feed lutein supplementation on mozzarella cheese quality and lutein stability

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ABSTRACT

The effect of lutein supplementation in feed on the lutein content in raw milk and the resulting mozzarella cheese, as well as cheese quality and lutein stability during storage, were determined. The lutein content in the raw milk was increased approximately 3-fold after 2 months of lutein feed supplementation. With regard to cheese quality, few significant differences were found in the cheese composition, water activity (a w) and texture. However, the b* value for the colour, and the stretchability was higher in the lutein-rich cheese. During the cheese-making process, most of the lutein remained in the cheese, but some was lost in the whey, hot water and brine. Approximately 20% lutein was lost during the 8 week storage period.

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1. Introduction

Lutein is a naturally occurring fat-soluble carotenoid (β, e-carotene-3, 3'-diol) belonging to the xanthophyll carotenoid family. Lutein is known for its ability to reduce or prevent ocular diseases including age-related macular degeneration, cataracts and diabetic retinopathy, and atherosclerosis (Mares, 2016; Muriach et al., 2006). Furthermore, numerous reports have suggested that dietary supplementation of lutein and other natural carotenoids can significantly prevent the development of many types of cancer and other chronic diseases (Luke et al., 2016; Mares-Perlman, Millen, Ficek, & Hankinson, 2002; Ribaya-Mercado & Blumberg, 2004).

Lutein is the second most prevalent carotenoid in human serum, and it is present mainly in leafy greens, such as spinach, collard greens, turnip greens and kale (Sommerburg, Keunen, Bird, & van Kuijk, 1998). The presence of lutein in animals, on the other hand, is due to the ingestion of lutein-containing foods by the animals. The highest contents of lutein are found in egg yolk, chicken (broilers) and some dairy products (Nwachukwu, Udenigwe, & Atuko, 2016). Depending on the feed and breed, milk can be a good source of lutein with exceptional bioavailability, because the lutein is dissolved in the lipids within the milk fat globules (Schweiggert & Carle, 2015).

A previous study showed that the lutein content in milk was rapidly increased by shifting feed from a hay-based diet to one with high levels of carotenoids and vitamin E (Calderon et al., 2007). Our previous work also found that dietary lutein supplementation significantly improved both milk yield and lutein content. In addition to the improved plasma antioxidative activity, lutein supplementation in feed increased milk fat content and lactose concentration (Xu et al., 2014).

Milk has long been regarded as a natural delivery vehicle for many bioactive compounds including lutein (Yeeum & Russell, 2002; Yi, Fan, Yokoyama, Zhang, & Zhao, 2016). In addition to the incorporation of lutein into foods through technological advances as mentioned above, studies have been conducted on the direct fortification of lutein in milk (Matsumoto et al., 2014), reconstituted milk (Odorissi Xavier, Mercadante, Garrido-Fernández, & Pérez-Gálvez, 2014), infant formula (Capeding et al., 2010) and other dairy products such as fermented milk (Granado-Lorencio, Herrero-Barbudo, Olmedilla-Alonso, Blanco-Navarro, & Pérez-Sacristán, 2010), yoghurt (Domingos et al., 2014) and cheese (Jones, Aryana, & Losso, 2005; Tokugouli, 2013). The limited data available have suggested that the bio-accessibility of lutein was lower in reconstituted products than in liquid milk and yoghurt (Odorissi Xavier et al., 2014). Several studies on the bio-availability of lutein revealed that serum lutein concentrations were much higher in breastfed infants than in infants fed with fortified formula (Bettler, Zimmer, Neuringer, & DeRusso, 2010; Kullen et al., 2007; Tso, Vurma, Lee, & DeMichele, 2016).
Our previous work found feed lutein supplementation could improve milk performance (Xu et al., 2014), milk lutein content and milk flavour (unpublished data). However, the effect of lutein on cheese quality is still unclear. Therefore, the aim of this study was to determine the effects of feed lutein supplementation on mozzarella cheese lutein content, cheese quality and lutein stability during cheese storage.

2. Materials and methods

2.1. Milk sample preparation

The milk samples used in this study were obtained from a local dairy farm, Qiaoshi Dairy Farm, Hangzhou, Zhejiang Province. Sixteen multiparous Holstein cows in mid-lactation were selected and divided evenly into two groups. Group A, the control, was fed basal diet only. Group B received a basal diet containing lutein supplementation at 200 g d⁻¹ per head (an effective dose of 4 g d⁻¹ per head); the diet was formulated and managed according to our previous work (Xu et al., 2014). Milk samples were collected and stored at −20 °C until further lutein content determination, as described below.

2.2. Cheese-making

The raw milk used for cheese-making was sampled from the same place and at the same time from cows with or without feed lutein supplementation. The raw milk (30 L) was standardised to a protein-to-fat ratio of 3.1:3.5 by partial skimming, and the milk was pasteurised at 63 °C for 30 min and then cooled to 35 °C. Mozzarella cheese was made as described in a previous study with some modifications (Sheehan & Guinee, 2004). The milk was inoculated with a starter culture (TCC-3, Chr. Hansen, Hørsholm, Denmark). When the pH of the milk had decreased by 0.1 pH unit, chymosin Stanix 1150 (Chr. Hansen) was added. After 30 min, the curd was cut with 1-cm knives and allowed to heal for 15 min. The temperature was increased to 42 °C at a rate of 0.2 °C min⁻¹, and the curd was cooked for 30 min. After the whey was removed, the curd was trench, cut into slabs, turned, and stacked until the pH dropped to approximately 5.2–5.3. The curds were then milled and dry salted (2%, w/w, of curd) prior to being mechanically heated, stretched under hot water (10 L, 80 °C) until the central temperature of the curd increased to 66 °C, and then moulded. The curds were formed into 1 kg loaves, immersed in 2% brine (10 L, 4 °C) overnight, and stored in vacuum-sealed barrier bags (PET/AL/PE, Haixin packaging materials Co., Ltd, Suzhou, China) at 4 °C until analysis.

The standardised milk, curd, whey, hot water and brine from the preparation of the lutein-rich cheese were collected and frozen until the lutein content was analysed. The control cheese was manufactured and analysed as described previously using milk from cows that had not been fed lutein supplement.

2.3. Compositional and water activity analysis

The fat content of the cheese was determined with the Gerber method (NSAI, 1955), the moisture content was determined with the oven-drying method (IDF, 1958), and the protein content was determined with the macro-Kjeldahl method (IDF, 1993). The pH was measured by inserting a calibrated Unicam glass Ag/AgCl combination pH electrode attached to a pH metre (Seven Easy® Plu; Mettler-Toledo, Zurich, Switzerland) directly into the cheese at six randomly chosen locations. The water activity (aₜ) was measured using a HygroPalm AW1 (Rotronic, Basserdorf, Switzerland). The calcium content of the samples was determined using standard IDF methods (IDF, 1992). The moisture content of the non-fat substances (MNS) and the fat content of the dry matter (FDM) were calculated based on the results of the individual constituents. All analyses were performed in triplicate.

2.4. Texture profile analysis

Cheese samples (16 mm diameter × 20 mm height) were prepared using a 16-mm diameter, cylindrical sampling device, and were put in room temperature (20 °C) for 1 h before test. The textural properties were measured using a texture analyser (TA-XT Plus; Stable Micro Systems, Godalming, UK) fitted with a P/0.5S probe. Cylindrical cheese samples were compressed twice to 50% of the original height at a speed of 1 mm s⁻¹. Hardness, chewiness, adhesiveness and cohesiveness of the cheeses were calculated as described previously (Bourke, 1978). The analyses were conducted in triplicate.

2.5. Colour measurements

Colour analyses were performed using a handheld Minolta CR-20 colourimeter (Minolta Laboratories, Osaka, Japan). The L*, a*, and b* colour measurements were determined according to the CIELAB colour space. The L* value corresponds to the lightness (varies from 0% dark to 100% light), the a* value corresponds to red/green (varies from −60% green to +60% red), and the b* value corresponds to yellow/blue chromaticity (varies from −60% blue to +60% yellow) (Pinho, Mendes, Alves, & Ferreira, 2004). On average, 5 readings per sample were recorded.

2.6. Cheese functionality after heating

The cheese functionality, including the meltability, stretchability, and flowability, was tested after heating. The flowability was measured with a modified Schreiber method and is defined as the percentage increase in the diameter of a disc of cheese (Guinee, Harrington, Corcoran, Mulholland, & Mullins, 2000). The cheese was 45.5 mm diameter and 6.5 mm thick, it was melted at 280 °C for 4 min in an electric fan oven. The meltability of the cheeses was determined using the Arnott test (Park, Rosenau, & Peleg, 1984), which measures the change in the sample height after heating at 100 °C for 15 min. The stretchability of the molten cheese (280 °C for 4 min) was measured using a fork test (Wadhwani, McManus, & McMahon, 2011). One minute after baking, a stainless steel, 4-pronged fork was inserted into the cheese (three different places of cheese surface) and then lifted vertically, and the distance the cheese could be lifted before breaking was measured. All tests were performed in triplicate.

2.7. Lutein content and distribution determination

The lutein contents in the milk, cheese, whey, hot water and brine were analysed using reverse phase-high performance liquid chromatography (RP-HPLC) according to a previously published work (Gill & Indyk, 2008). The sample preparation procedure was adapted from the method used for the rapid analysis of carotenoids in bovine milk (Gill & Indyk, 2008; Jones et al., 2003). One gram of solid (cheese or curd) or 1 mL of liquid (milk, whey, hot water or brine) sample was weighed accurately and placed into a tube, 10 mL of 1% (w/v) ethanolic pyrogallol was added, and then 2 mL of a 50% (w/v) KOH solution was added. After incubation and agitation, 20 mL of the extraction solution (hexane:disopropyl ether; 75:25, v/v) was added, and the mixture was shaken for 5 min. Twenty millilitres of deionised water was added, and the tubes were shaken and centrifuged for 10 min at 2000× g. A 1-mL aliquot of the upper solvent layer was transferred to an HPLC vial.
Lutein and lutein esters were separated on an Agilent 1200 HPLC system (Agilent Technologies Inc., Palo Alto, CA, USA) equipped with a diode array and multi-wavelength detector. A 20 μL aliquot of the milk extract was injected into a polymeric reversed-phase ZORBAX C18 column (250 × 4.6 mm, 5 μm particle size, Agilent Technologies). A pre-column (12.5 × 4.6 mm, 4 PK-1) was used to protect the column. The separation was isocratic using methyl tertiary-butyl ether (TBME): methanol (5:95, v/v) as the mobile phase, and the total separation time was 30 min. The flow rate was 1.0 mL min⁻¹, and the detection wavelength was set at 450 nm.

2.8. Experimental design and statistical analysis

Sixteen multiparous Holstein cows in mid-lactation were selected and divided into two groups randomly. Cows were fed three times a day with or without lutein supply (4 g d⁻¹) and milking three times per day according to our previous work (Xu et al., 2014). After two months feeding, two groups of the raw milk (mixed from thrice milking) were collected for cheese making. Raw milk was continuously collected three times and then mozzarella cheese was made respectively. All of the cheese samples were analysed three times.

An independent t-test was applied to analysis the difference of cheese composition, colour and texture properties between control and lutein-rich cheese. For cheese ash, pH and functional properties during the storage, analysis of variance (ANOVA) was carried out using the general linear model (GLM) of the SPSS statistical software package (17.0). Tukey pairwise comparisons were performed for significant differences. All differences were considered statistically significant at P < 0.05.

3. Results and discussion

3.1. Lutein content and distribution in milk and cheese

The lutein contents in the control and lutein-rich milk were 5.15 and 15.25 μg L⁻¹ (Table 1), respectively. After 2 months of feeding with lutein-fortified feed, the lutein content in milk was increased approximately 3-fold. Similar results were found in other studies using different kinds of lutein supplementation in feed. When researchers added lutein-fortified chlorella to the feed diets, the lutein content in the milk increased by 3.1 times that of the control after 3 wk of feeding and was higher than that of the milk corresponding to feed supplemented with conventional chlorella (Jeon et al., 2016). Our previous study also showed that lutein content increased 4-fold after 2 months of feeding with lutein-supplemented feed (Xu et al., 2014). However, the content of lutein in milk was not enhanced significantly following a shift from a hay diet to diets with increasing levels of carotenoids (Calderon et al., 2007). The results of these studies show that the lutein content in milk was influenced by the content of lutein or a lutein precursor in the diet.

The lutein content in cheese and lutein loss during the cheese-making process are shown in Table 1. Lutein contents in both cheeses were 40.3 μg kg⁻¹ for control and 113.6 μg kg⁻¹ for lutein-rich cheese, the percentage of lutein remaining in both cheeses based on standardised milk was 75.4 and 78.2%, respectively. For the lutein loss, most of the lutein was lost to the whey, and the subsequent values were 1.02 and 2.17 μL⁻¹ for control (20.5%) and lutein-rich cheese (15.3%), respectively. Lutein was also lost to the hot water during stretching (2.75%) and the brine (1.37%) in the lutein-rich cheese; the contents of lutein in the stretch water and brine were too low to detect in control. Lutein is a natural fat-soluble xanthophyll carotenoid that is present in milk fat, and during the cheese-making process, most fat-soluble carotenoids go into the cheese with the fat, while the rest is lost in the whey, hot water and brine. During cheese-making, most of the lutein went into the cheese, but approximately 15–20% of the lutein was lost to the whey, and the rest was lost in the stretch water and brine. These results show that it is possible to produce high lutein foods, such as cheese, by feed lutein supplementation.

3.2. Effect of feed lutein supplementation on cheese quality

3.2.1. Cheese composition and physico-chemical properties

Data on the gross composition of the feed lutein-supplemented and control cheeses are summarised in Table 2. The protein, fat, and ash contents did not significantly differ between the lutein-rich and control cheeses. This may due to the similarities of their milk composition. As in our previous study, feed lutein supplementation (200 g d⁻¹) could improve the milk yield (2.8 kg d⁻¹); however, the milk protein and fat contents remained the same (Xu et al., 2014). The total Ca contents of the cheeses were also not significantly different, presumably due to the use of similar draining pH values in both treatments. However, the Ca/protein was higher in lutein rich cheese (P < 0.05). The cheese composition results showed that feed lutein supplementation does not significantly affect the composition of raw milk or that of the resulting mozzarella cheese.

The pH and water activity (aw) of the two cheeses during the two months storage period are shown in Table 3. The pH values of the two cheeses were similar at the beginning. In the control cheese, pH was 5.19 ± 0.05 during storage, which was similar to the lutein-rich cheese (5.23 ± 0.16) and control cheeses are similar at the beginning. In the control cheese, pH was 5.19 ± 0.05 during storage, which was similar to the lutein-rich cheese (5.23 ± 0.16) and control cheeses. This may due to the similarities of their milk composition. As in our previous study, feed lutein supplementation does not significantly affect the composition of raw milk or that of the resulting mozzarella cheese.

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Table 1

<table>
<thead>
<tr>
<th>Lutein</th>
<th>Control</th>
<th>Lutein-rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>(μg L⁻¹)</td>
<td>%</td>
<td>(μg L⁻¹)</td>
</tr>
<tr>
<td>Raw milk</td>
<td>5.15 ± 0.13</td>
<td>15.25 ± 0.05</td>
</tr>
<tr>
<td>Standardised milk</td>
<td>4.96 ± 0.12</td>
<td>14.62 ± 0.05</td>
</tr>
<tr>
<td>Curd (μg kg⁻¹)</td>
<td>34.52 ± 2.56</td>
<td>93.94 ± 3.41</td>
</tr>
<tr>
<td>Cheese (μg kg⁻¹)</td>
<td>40.4 ± 3.11</td>
<td>113.6 ± 5.25</td>
</tr>
<tr>
<td>Whey</td>
<td>1.02 ± 0.11</td>
<td>2.17 ± 0.23</td>
</tr>
<tr>
<td>Hot water</td>
<td>ND</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Brine</td>
<td>ND</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

* Lutein percentage in different parts was based on standardised milk (100%); ND, not detected.

Table 2

<table>
<thead>
<tr>
<th>Composition</th>
<th>Control</th>
<th>Lutein-rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>25.2 ± 0.32</td>
<td>24.5 ± 0.65</td>
</tr>
<tr>
<td>Fat</td>
<td>24.7 ± 0.60</td>
<td>23.1 ± 0.37</td>
</tr>
<tr>
<td>Moisture</td>
<td>44.3 ± 1.07</td>
<td>47.1 ± 0.49</td>
</tr>
<tr>
<td>Ash</td>
<td>4.41 ± 0.46</td>
<td>4.13 ± 0.32</td>
</tr>
<tr>
<td>FDM</td>
<td>44.4 ± 2.18</td>
<td>43.7 ± 0.93</td>
</tr>
<tr>
<td>MNFS</td>
<td>590 ± 2.12</td>
<td>62.5 ± 0.87</td>
</tr>
<tr>
<td>Ca (mg kg⁻¹)</td>
<td>479 ± 4.71</td>
<td>498 ± 7.45</td>
</tr>
<tr>
<td>Ca/protein</td>
<td>1.99 ± 0.05</td>
<td>2.03 ± 0.07</td>
</tr>
<tr>
<td>l</td>
<td>88.6 ± 1.29</td>
<td>86.1 ± 0.91</td>
</tr>
<tr>
<td>a</td>
<td>8.55 ± 0.64</td>
<td>7.63 ± 1.70</td>
</tr>
<tr>
<td>b</td>
<td>12.7 ± 1.79</td>
<td>16.8 ± 0.44</td>
</tr>
</tbody>
</table>

* Abbreviations are: FDM, fat in dry matter; MNFS, moisture in non-fat substances. Means for moisture, Ca/protein and b are significantly different between the two groups (P < 0.05).
control \((P < 0.05)\). The increase in pH during storage may be due to losses of lactic acid, soluble calcium and phosphate to the stretch water and to the re-solubilisation of micellar calcium phosphate upon cooling the cheese after plasticisation (Guinee, Feeney, Auty, & Fox, 2002).

The water activity \((a_w)\) during storage did not significantly differ between the two types of cheese. Compared with 0 wk, the \(a_w\) was lower \((P < 0.05)\) after 8 wk storage in lutein rich cheese. This difference may be related to the effect of microorganism on casein matrix. However, the effect of lutein on bacterial or LAB is still unclearly, further study is still needed.

### 3.2.3. Colour

Colour is an important criterion used to evaluate cheese quality, and it is a primary consideration for consumers when making purchasing decisions. The colour differences between the control and lutein-rich cheeses are shown in Table 4. The \(L^*\), \(a^*\) and \(b^*\) values for the control were 88.6, 8.56 and 12.7, respectively, while those of the lutein-rich cheese were 86.1, 7.63 and 16.8, respectively. No significant difference in the mean \(L^*\) value was found between the control and lutein-rich cheese. A similar result was found by Jones et al. (2005) in cheddar cheese fortified with 6 mg of lutein. However, no significant difference was found in yoghurt fortified with lutein.

Our result was not consistent with those of other studies on milk or cheese fortified with lutein. Jones et al. (2005) found the difference in redness between cheddar cheese enriched with 1–6 mg of lutein and the control was significant. Aryana et al. (2006) also found the \(a^*\) value of strawberry yoghurt fortified with approximately 0.5–3 mg lutein was higher than that of the control. The \(a^*\) value is a measure of the redness-to-greenness of the product. Lutein is a red-coloured carotenoid, which is why milk or cheese fortified with lutein will show more redness. In this study, the \(b^*\) value is significantly higher in the lutein-rich cheese. A similar result was found by Jones et al. (2005) in cheddar cheese fortified with 6 mg of lutein.

3.2.4. Functionality of heated cheese

The changes in the functional characteristics of the two cheeses during the eight-week storage period are shown in Fig. 1. The two cheeses did not significantly differ at the beginning; however, the stretchability of the lutein-rich cheese was significantly higher than that of the control after eight weeks storage.

In agreement with previous studies (Sheehan & Guinee, 2004), the mean meltability, flowability and stretchability of both cheeses significantly increased during the storage period. These changes may be attributed to the increase in casein hydration and decrease in intact casein content as microorganisms and enzymes (Guinee et al., 2002; Sheehan & Guinee, 2004).

The stretchability of the lutein-rich cheese was significantly higher during storage \((P < 0.05)\). This difference was in line with our expectations because both parameters depend on the displacement of the para-casein matrix. This difference could partly attribute to higher Ca/protein ratio in lutein-rich cheese, which may affect the para-casein matrix during the cheese ripening. Because of the higher degree of protein cross-linking and higher levels of primary proteolysis, the degree of displacement for a given stress applied during the extension was expected to increase for the lutein-rich cheese (Sheehan & Guinee, 2004).

### 3.3. Lutein stability in cheese during the storage period

The lutein content in the two kinds of cheese during the 8-wk storage period are shown in Fig. 2. The lutein content was reduced during storage; 8.3 \(\mu\)g \(\text{kg}^{-1}\) was lost from the control \((20.4\%)\), and 23.5 \(\mu\)g \(\text{kg}^{-1}\) \((20.6\%)\) was lost from the lutein-rich cheese \((P < 0.01)\). Calculated based on the standardised milk, the lutein loss during the storage was 15.5% and 16.2% respectively, and lutein in final cheese was 64.7% and 62.0% left for control and lutein rich cheese.

Conjugated double bonds are present in lutein, which makes lutein sensitive to light; lutein degrades mainly at wavelengths between 200 and 400 nm, but degradation has been observed at 463 nm in some model beverages (Kline, Duncan, Bianchi, Eigil, & O’Keefe, 2011). Some researchers have found the lutein content was reduced during storage; in another study evaluating the addition of lutein to skimmed yoghurt, the carotenoid content had decreased by almost 10% of its initial concentration at the end of 5 weeks storage (Aryana et al., 2006; Tokusoglu, 2013) added different concentrations of lutein to cream cheeses and found that lutein levels did not affect the product flavour. Moreover, this carotenoid

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**Table 3**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Storage (wk)</th>
<th>(a_w) ± SE (P)</th>
<th>pH ± SE (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0.973 ± 0.003(a)</td>
<td>5.19 ± 0.03(b)</td>
</tr>
<tr>
<td>Lutein-rich</td>
<td>0</td>
<td>0.971 ± 0.005(a)</td>
<td>5.16 ± 0.03(b)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.969 ± 0.009(ab)</td>
<td>5.18 ± 0.04(a)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.968 ± 0.003(b)</td>
<td>5.14 ± 0.04(a)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.965 ± 0.005(a)</td>
<td>5.08 ± 0.02(a)</td>
</tr>
</tbody>
</table>

\(a\) Means within a column with the same superscript letter are not significantly different \((P < 0.05)\).

**Table 4**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Control</th>
<th>Lutein-rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (g)</td>
<td>437 ± 56</td>
<td>387 ± 39</td>
</tr>
<tr>
<td>Adhesiveness (g sec)</td>
<td>22.1 ± 5.57</td>
<td>52.2 ± 14.2</td>
</tr>
<tr>
<td>Chewiness</td>
<td>277 ± 59</td>
<td>145 ± 38</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>965 ± 0.04</td>
<td>0.47 ± 0.05</td>
</tr>
</tbody>
</table>

\(a\) Means for chewiness are significantly different between the two groups \((P < 0.05)\).
remained stable for approximately 6 weeks storage (Tokusoglu, 2013). Other researchers found lutein is stable during the storage: Jones et al. (2005) observed there was a little lutein degradation during storage of lutein-enriched cheddar cheeses over a 24-wk period at 4.5 °C.

Besides cheese-making, lutein could be lost by oxidative mechanisms during cheese ripening (Jones et al., 2005). Therefore, the concentration of lutein in cheeses during ripening was monitored. During the cheese ripening, about 20% lutein was oxidative lost, nearly 80% of lutein in cheese was left. The results of those studies show that both lutein fortified in feed and lutein added directly to milk are stable during cheese processing and storage. Vacuum packaging and low temperature storage may be the main reasons for the small amount of lutein lost during storage.

4. Conclusions

The lutein content in milk was greatly increased by dietary lutein supplementation. During subsequent mozzarella cheese-making, approximately 80% of the lutein remained in the cheese, while the rest was lost in the whey, hot water and brine. Compared with the control, no significant differences in composition, aw or texture was found in the lutein-rich cheese. For the colour parameters, the b* value was higher in lutein-rich cheese, but the L* and a* values were similar. For the functional properties, no significant differences were found in flowability and meltability, but the stretchability was higher in lutein-rich cheese. During storage, the lutein was stable in both cheeses. Briefly, feed lutein supplementation is an optional choice for producing natural lutein rich milk product such as cheese or milk.

Acknowledgements

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