Collaborative effect of fat reduction and α-tocopherol incorporation on oxidative stability in beef sausages

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Abstract. This study focuses on the changes in oxidative stability and sensory properties of reduced fat and/or α-tocopherol incorporated sausages during storage at 4°C for 3 months. In order to examine these changes, sausages were formulated with 20% fat and 20% fat+200 ppm α-tocopherol, coded as C20A0 and C20A1, respectively. Sausages formulated with 10% fat (C10A0) and 10% fat+200 ppm α-tocopherol (C10A0) were low fat sausages. Reduction of fat by 50% or adding α-tocopherol initially increased the peroxide values of sausages, but at the end of storage, conversely, reduction of fat and α-tocopherol addition retarded lipid peroxidation as well as malonaldehyde generation (p<0.05). The highest thiobarbituric acid reactive substance values were recorded for C20A0 sausages initially and at the end of the storage (p<0.05). Even though thiobarbituric acid reactive substance values of sausages with 20% fat were higher, the initial rancid taste of all sausages were similar at month 0, but differences in the rancid taste of sausages began to be revealed with increasing storage time (p<0.05). No significant differences were found in the general acceptability of all the sausages during the 3-month storage period (p>0.05).

1. Introduction

Meat and meat products are valuable sources of important food components such as proteins, essential amino acids, minerals and vitamins [1]. Despite the nutritious value of meat and meat products [2], fat contents of meat products have caused negative perceptions in consumers towards consumption of these products due to the fat-linked health problems such as cardiovascular diseases, obesity and some cancer types [3]. The World Health Organization also recommended that total fat consumption should not exceed 30% of total energy intake [4,5]. However, emulsion type meat products can be formulated with fat content up to 30% [6].

Lipid oxidation reactions that limit the shelf life of meat products are induced from high fat content. These reactions create unfavorable changes in product quality besides their adverse effect on health due to generation of toxic compounds as a result of chain reactions [7]. Oxidative changes can be retarded by lowering the fat content or with antioxidant compounds. Sequestration of free radicals from the medium, chelation of metallic ions, inhibition of free radical-producing enzymes, activation of endogenous antioxidant enzymes, prevention of lipid peroxidation, prevention of DNA damage,
prevention of protein modification and sugar destruction are some important mechanisms of antioxidants [8].

Given these circumstances, the need for low fat or antioxidant-added meat products has arisen [9]. Nevertheless, when the fat content is decreased, acceptance of meat products by consumers weakened due to the decreased mouthfeel, texture and juiciness properties provided from fat. Thus, designing low fat meat products is a reasonably troublesome topic [10,11].

In this study, the effects of decreasing beef fat content from 20% to 10% in sausages and incorporating α-tocopherol in the sausage formulation on oxidative changes and some sensory properties during 3-month storage at 4°C were studied.

2. Materials and methods
Four different emulsion type sausage formulations were prepared (Table 1). Minced beef and beef fat were purchased from a local butcher, α-tocopherol was obtained from Kimbiotek (İstanbul-Turkey). Minced beef, curing ingredients and half of the ice were homogenized and ground for 1 min in a cutter (Alpina-Schweiz). Other ingredients added (to 5000 g of sausage batter) to all sausages were: 1.5% salt, 0.15% sugar, 0.15% sodium tripolyphosphate, 0.09% ascorbic acid, 150 ppm sodium nitrite, 3% powdered milk, 3% sodium caseinate, 4% starch, 1.5% bread crumbs, 0.9% spices. Fat, α-tocopherol (depending on formulation; Table 1), the other ingredients and the remainder of the ice was added to the meat and mixed for one more minute. Finally, batters were homogenized for 3 minutes. Sausage batters were stuffed into casings and smoked in smokehouse at 40°C for 2 h (Afos-England), then heat treated in a boiling vessel until the core temperature reached 70°C. Once heating was completed, sausages were cooled, vacuum packaged and stored at 4°C for 3 months. Oxidative changes of sausages were determined in terms of peroxide values [12] and thiobarbituric acid reactive substances (TBARS) [13]. Sensory properties of sausages were evaluated in terms of oiliness, rancid taste and general acceptability (1: not like, 9: extremely like). Data was analyzed by ANOVA and Duncan’s Post-Hoc tests using SPSS 23 software.

Table 1. Formulation of sausages

| Sausage* | Beef meat (g) | Beef fat (g) | Ice (g) | α-Tocopherol |
|----------|--------------|-------------|--------|--------------|
| C20A0    | 3000         | 1000        | 1000   | -            |
| C20A1    | 3000         | 1000        | 1000   | 200 ppm      |
| C10A0    | 3000         | 500         | 1500   | -            |
| C10A1    | 3000         | 500         | 1500   | 200 ppm      |

*Sausage denomination: C20A0 (Control group, 20% beef fat), C20A1 (Control group, 20% beef fat with 200 ppm α-tocopherol), C10A0 (Reduced fat control group, 10% beef fat), C10A1 (Reduced fat control group, 10% beef fat with 200 ppm α-tocopherol).

3. Results and discussion
Peroxide values of sausages were between 0.391 and 2.749 meqO₂/kg during the 3-month storage (Table 2). At the beginning, the lowest and highest peroxide values were measured in C20A0 and C10A1 sausages, respectively (p<0.05). Storage period had a significant effect on the sausages’ peroxide values (p<0.05). During storage, peroxide values of C20A0 sausages increased continuously up to month 3 (p<0.05). Peroxide values of C20A1 sausages increased after the 1st month of storage, but in C10A0 sausages, values decreased after 2 months of storage (p<0.05). At the end of the storage, lipid peroxidation was affected by fat reduction and α-tocopherol addition (p<0.05). Beef fat at the higher level (20%) induced higher peroxide values than were measured in 10% beef fat sausages (p<0.05). Addition of α-tocopherol did not retard the oxidation of sausages formulated with 10% beef fat (p<0.05). Incorporating α-tocopherol to pork patties delayed the lipid oxidation after 20 days of
storage [14]. In our study, the peroxide values of all sausages were lower than 25 meqO$_2$/kg, which is the limit for fatty foods [15].

| Sausage | Month 0   | Month 1          | Month 2          | Month 3          |
|---------|-----------|------------------|------------------|------------------|
| C20A0   | 0.777±0.018$^{b,z}$ | 1.107±0.097$^{ab,yz}$ | 1.735±0.344$^{ab,y}$ | 2.749±0.743$^{ax}$ |
| C20A1   | 1.020±0.099$^{ab,y}$  | 0.720±0.110$^{bc,y}$  | 2.229±0.577$^{ax}$  | 1.688±0.114$^{b,x}$ |
| C10A0   | 1.058±0.111$^{ab,z}$  | 1.259±0.560$^{a,x}$  | 1.193±0.203$^{c,x}$  | 0.524±0.226$^{c,y}$  |
| C10A1   | 1.717±0.697$^{a,x}$  | 0.393±0.001$^{c,y}$  | 1.252±0.114$^{c,x}$  | 0.391±0.004$^{c,y}$  |

Data are presented as the mean values of replications ± standard deviation. abc: Means with the different letter in the same column are significantly different (p<0.05); Data are presented as the mean values of replications ± standard deviation. xyz: Means with the different letter in the same row are significantly different (p<0.05).

TBARS values of sausages are given in Table 3. The highest initial TBARS value was determined in the control group produced with 20% beef fat without α-tocopherol (p<0.05). All sausage groups except C20A0 showed similar initial TBARS values. Using antioxidant had an effect on TBARS value only in the presence of 20% fat in the formulation. Reduction of fat in the formulation lowered the TBARS values both initially and at the end of the storage (p<0.05). During storage, TBARS values of C20A1 sausages increased up to the 2nd month, but afterwards, decreased TBARS values were measured, even though the final values were higher than initial values (p<0.05). TBARS values of C10A0 and C10A1 sausages fluctuated during the 3-month storage. At the end of the storage, sausages formulated with 20% beef fat showed higher TBARS values than sausages formulated with 10% beef fat (p<0.05). Similar to the initial pattern of peroxide values, using α-tocopherol was found to effectively retard the oxidative changes only in sausages with 20% fat. The TBARS values of all sausages remained within the acceptable limit of TBARS, i.e. lower than 2.0 mg MA/kg sample [13] throughout the 3-month storage, most probably because of vacuum packaging. α-tocopherol showed its antioxidant effect by singlet oxygen scavenging and radical chain reaction breaking [16]. C10A0 and C10A1 sausages showed no differences from each other while these values were lower than other two sausage types. Similar to our results, Olivares et al. [6] reported that dry fermented sausages formulated with 30% fat had higher TBARS values than samples with 10% fat content. In another study, using α-tocopherol in pork patties retarded the oxidative changes compared to control groups with no antioxidant [17].

| Sample  | Month 0   | Month 1 | Month 2   | Month 3   |
|---------|-----------|---------|-----------|-----------|
| C20A0   | 0.426±0.08$^{a,y}$ | 0.109±0.014$^{a,z}$ | 0.541±0.179$^{a,xy}$ | 0.747±0.155$^{a,ax}$ |
| C20A1   | 0.192±0.05$^{b,y}$ | 0.206±0.013$^{b,y}$ | 0.742±0.191$^{a,x}$ | 0.541±0.149$^{ab,x}$ |
| C10A0   | 0.251±0.013$^{b,yz}$ | 0.144±0.026$^{b,z}$ | 0.539±0.089$^{ax}$ | 0.316±0.148$^{c,y}$ |
| C10A1   | 0.227±0.021$^{b,y}$ | 0.088±0.006$^{c,z}$ | 0.440±0.120$^{a,x}$ | 0.345±0.039$^{c,xy}$ |

Data are presented as the mean values of replications ± standard deviation. abc: Means with the different letter in the same column are significantly different (p<0.05); Data are presented as the mean values of replications ± standard deviation. xyz: Means with the different letter in the same row are significantly different (p<0.05).

Sensory properties of sausages in terms of oiliness, rancid taste and general acceptability are shown in Table 4. Fat reduction significantly affected the oiliness scores of C10 sausages (p<0.05). At the beginning of storage, panelists did not score a rancid taste in any of the sausages and no significant difference was found in general acceptability of sausages (p>0.05).
Sensory properties of sausages decreased during storage and the lowest general acceptability result of C20A0 sausage was found in the 3rd month (p<0.05) due to higher oxidative changes in this formulation. TBARS results were similar; a more rancid taste was found in C20A0 sausage, which had the highest TBARS values at the end of storage. Reduced fat and α-tocopherol-added sausages (C10A1) had the lowest rancid taste scores at the end of storage (p<0.05). However, all sausages had similar general acceptability scores at this time (p>0.05). It can be stated that the use of antioxidant in reduced fat sausage produced significant effect on delaying rancid taste development (p<0.05).

4. Conclusion
Since high fat content is related to some health problems, formulating meat products with lower fat content could be a good strategy. In this study, it was seen that lowering the fat content by 50% (so they contained just 10% fat) and adding α-tocopherol to sausages retarded the oxidative changes at the beginning and at the end of the storage. Even though fat has important effects on sensory properties of meat products, fat reduction did not affect the general acceptability of sausages at the end of storage. However, similar to oxidation results, the addition of α-tocopherol inhibits rancid taste development in sausages containing just 10% beef fat.

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Table 4. Sensory analysis of sausages

| Sausage | Storage (month) | Oiliness | Storage (month) | Rancid Taste | Storage (month) | General Acceptability |
|---------|-----------------|----------|-----------------|--------------|-----------------|-----------------------|
|         | 0               | 1        | 2               | 3            | 0               | 1         | 2 | 3 |
| C20A0   | 6.6             | ±0.5b,y  | 7.2             | ±0.4a,x      | 6.8             | ±0.6a,y   | 6.1         | ±0.5a,x      | 1.6          | ±0.6a,y      | 2.2          | ±0.5a,y      | 2.7          | ±0.5a,y      | 3.2          | ±0.8a,x      | 6.5          | ±0.5a,x      | 6.1          | ±0.7a,y      | 6.0          | ±0.7ab,y     | 5.6          | ±0.5a,y      |
| C20A1   | 6.7             | ±0.8a,b,y| 7.06            | ±0.7a,x      | 6.9             | ±0.6a,x   | 6.4         | ±0.5a,b,y    | 1.5          | ±0.5a,b,y    | 1.9          | ±0.7b,y      | 2.5          | ±0.5b,y      | 6.5          | ±0.5a,x      | 5.8          | ±0.6a,y      | 5.7          | ±0.5b,y      | 5.7          | ±0.5a,y      |
| C10A0   | 7.3             | ±0.5a,b,y| 7.2             | ±0.4a,x      | 7.2             | ±0.6a,y   | 6.8         | ±0.4a,b,y    | 1.2          | ±0.5a,b,y    | 2.3          | ±0.7b,y      | 2.7          | ±0.5b,y      | 6.5          | ±0.5a,x      | 6.2          | ±0.8a,x      | 6.3          | ±0.5a,x      | 6.0          | ±0.5a,x      |
| C10A1   | 7.5             | ±0.7a,x  | 7.4             | ±0.5a,x      | 7.0             | ±0.7a,x   | 6.9         | ±0.4a,b,y    | 1.3          | ±0.5a,b,y    | 1.6          | ±0.7b,y      | 1.9          | ±0.7b,y      | 6.3          | ±0.4a,b,y    | 6.4          | ±0.7b,y      | 6.0          | ±0.7b,y      | 6.0          | ±0.7b,y      |

Data are presented as the mean values of replications ± standard deviation. abc: Means with the different letter in the same row are significantly different (p<0.05); Data are presented as the mean values of replications ± standard deviation. xyz: Means with the different letter in the same row are significantly different (p<0.05).
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