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Use of Sweet Sorghum Syrup as an Antioxidant in Fresh Pork Sausage

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ABSTRACT

Sweet sorghum is a high-biomass and sugar yielding crop. A product of sweet sorghum is the production of sorghum syrup, which has been reported to be a sweetener with antioxidant capabilities. Food ingredients that have more than one function are considered multifunctional food ingredients; thus, the objective of this research was to determine if sweet sorghum syrup would decrease oxidation during retail display of fresh pork sausage patties compared to corn syrup. Picnic pork shoulders were purchased to generate fresh pork sausage patties. Three batches of sausage were made with each batch assigned to one of three treatments: 1) 1.8% corn syrup that had a 63-dextrose equivalent (Control), 2) 1.8% sorghum syrup (Trt-1), and 3) 3.6% sorghum syrup (Trt-2). The final product was formed into 151 g patties (18/treatment; n = 54), and patties were randomly placed in a simulated retail storage environment. The trial was replicated following the completion of the first trial. There was no difference ($P > 0.05$) between treatments in lipid oxidation as measured by thiobarbituric acid reactive substance, even though lipid oxidation increased ($P < 0.05$) after day 7 for all treatments. There were interactions for treatment and storage day for oxidation of myoglobin (discoloration). The Control patties were redder (greater a* values; $P < 0.05$) in color during the first 7 days compared to sorghum syrup treatments. Patties with 3.6% sorghum syrup had greater ($P < 0.05$) color intensity (chroma) than corn syrup on days 12 and 14. Furthermore, sorghum syrup treatments had more ($P < 0.05$) discoloration (hue angle) through day 7, and more ($P < 0.05$) discoloration (a*/b* ratio) through day 10. The variety of sweet sorghum syrup used in this study had little impact on oxidation and color of pork patties.

Additional index words: multifunctional ingredients, shelf-life, retail display

With the world's growing population, it is important for food producers, as well as consumers, to become more efficient with production and storage of food products to reduce food waste. Food waste is particularly challenging with regards to food items that are not preserved, such as fresh vegetables, fruit and meat. A common way to extend the shelf-life of meat, and limit food waste, is through altering the product by processing the meat to inhibit microbial growth (Sebranek, 2009) or limiting oxidation (Gray et al., 1996). Processed meat products are an alternative to fresh meat products, and frequently have antioxidants added to extend the shelf-life of the meat product.

One of the main reasons for short shelf-lives in meat products in the retail environment is oxidation. Oxidation is the process of oxygen removing a free radical from lipids located within the meat product (Halliwell, 2001) changing the color, odor, flavor and safety of the meat. Lipid oxidation can change the color of meat by increasing the amount of metmyoglobin (Greene, 1969). Thus, the addition of antioxidants to meat products can combat lipid oxidation as well as color change in meat (Faustman et al., 2010) during aerobic display. Antioxidants can be added to meat products and are effective against oxidation (Grun, 2009), thereby, extending the shelf life of the meat product. Antioxidants work by binding with free radicals (Sen et al., 2010) that oxygen would have bound to otherwise. Antioxidants have the ability to control oxidation and both synthetic and natural antioxidants exist. There are various examples of products that are natural antioxidants, such as potato peel extract (Kanatt et al., 2005a), mint (Kanatt et al., 2005b), mustard leaf (Lee et al., 2010), oregano oil (Scramlin et al., 2010), dried honey (Anthony et al., 2000), and sweet sorghum syrup (Willis et al., 2013). Natural antioxidants can have varying antioxidant abilities in terms of antioxidant products made from the same plant material (Cosentino et al., 2009). Natural antioxidants can also change in potency depending on the concentration used in the meat product (Sebranek et al., 2004).

Multifunctional ingredients in processed meats serve more than one function in the meat product. Examples of multifunctional ingredients include water, salt and natural antioxidants, all of which serve a primary purpose as well as contributing another attribute to the product (Sebranek, 2009). Natural antioxidants work in the functionality of the meat product, but also give flavor to the product (Grun, 2009; Sebranek, 2009). Sweet sorghum syrup is typically considered a sweetener, but, if it has antioxidant capabilities as identified by Willis et al. (2013), then it could potentially be a multifunctional ingredient in processed meats. If sweet sorghum syrup can be added as a multifunctional ingredient, then there could be an increase in demand for sweet sorghum syrup resulting in a need for an increase in production of sweet sorghum. However, sweet sorghum syrup has not been evaluated in processed meats as an antioxidant. Thus, the objective of this research was to determine if sweet sorghum syrup, if added as a sweetener, could limit oxidation in fresh pork sausage patties due to its naturally occurring antioxidants. The hypothesis was that inclusion of sweet sorghum syrup into fresh pork sausage patties would have less oxidation compared to patties with corn syrup when patties were stored in a retail environment.

MATERIALS AND METHODS

Pork Sausage. Vacuum sealed picnic pork shoulders (Institutional Meat Purchase Specification item number 405; USDA, 2014) were purchased for this study. The skin of the picnic shoulders was removed, and the shoulders were cut into pork trimmings, and trimmings were ground through a 9.5 mm plate, mixed and ground through a 4.8 mm plate. The ground pork was then divided into three 4.5 kg batches, and each batch contained the same spice mixture (1.26 % salt, 0.12 % ground black pepper, 0.05% ground white pepper, 0.05% ground nutmeg, and 0.02% ground clove). The three batches were then assigned to one of three sweetener treatments: 1) 1.8% corn syrup that had a 63-dextrose equivalent (Control); 2) 1.8% sorghum syrup (Trt-1); and 3) 3.6% sorghum syrup (Trt-2). Spices and sweeteners were mixed by hand for each batch, and the final mixed product was formed into 151-g patties using a 12-cm-diameter plastic die. Equal portions of the three different sample groups were retained, mixed, vacuum-packaged and stored as quality control. The patties were placed onto white no. 2 foam trays (Walton's Inc., Wichita, KS) measuring 21.1 cm W x 14.8 cm L x 2.7 cm D and overwrapped with aerobic polyvinyl chloride film (60-gauge, clear). Samples (18/treatment; n = 54) were randomly placed in a simulated retail storage environment.

Simulated Retail Storage Environment. The simulated retail storage environment included a temperature setting of 2^{o}C with continuous fluorescent lighting (bulb color temperature of 3000 K; color rendering index of 87; and average light intensity of 1630 lux). Groups of patties were then stored for 2, 4, 7, 10, 12 or 14 days (3 patties/treatment/d).

Color and TBARS. The colorimeter values were determined by using a MiniScan EZ Diffuse LAV (Hunter LAB, Hunter Associates Laboratory, Inc., Reston, VA) that had a diffuse geometry, 10^{o} observer angle, D65 illuminant, a pulse xenon halogen lamp, 20 mm diameter viewed area, and a 25 mm diameter port size. Three measurements of L*, a*, and b* were taken for each patty on the day of their respective storage period, and averaged to obtain one value for each color coordinate. The designated patties for each storage period were then removed from retail storage environment and were analyzed for oxidation by measuring thiobarbituric acid reactive substance (TBARS) using a filtration method (Scramlin et al., 2010). Briefly, a 5 -g representative sample of each patty was weighed and recorded. The 5-g samples were emulsified in a thiobabituric acid solution, and filtered through Whatman® filter paper 1. The filtrate was mixed with thiobabituric acid, a tetraethoxypropane solution and a phosphoric acid solution in 15-ml test tubes and incubated for 15 – 20 h. The filtrate (1.4 ml) for each sample was pipetted into a cuvette, and measured against (530 nm) wavelength in a spectrophotometer (DU700, Beckman Coulter, Inc., Fullerton, CA). The trial was replicated following the completion of the first trial.

Statistical Analysis. The TBARS and colorimeter data were analyzed using mixed model procedures of SAS (SAS Inst. Inc., Cary, NC). The fixed effects included replication, treatment, day and treatment x day interaction. Replication x treatment was utilized as a random effect. Least square means were separated using PDIFF option with differences detected at the $P < 0.05$ level.

RESULTS AND DISCUSSION

There was no difference ($P > 0.05$) between the Control, Trt-1 or Trt-2 in regards to TBARS absorbencies (0.112, 0.102, and = 0.102, respectively; SEM = 0.0145), and there was no treatment by day interaction ($P > 0.05$). This would indicate that fresh sausage patties with sweet sorghum syrup at concentrations of 1.8 and 3.6% had similar rates of lipid oxidation as fresh sausage patties with 1.8% corn syrup.

For all samples, over time TBARS values numerically increased with the exception from day 4 to day 7 where the TBARS value decreased (Table 1). However, there was only a significant increase ($P < 0.05$) from day 7 to day 10, and an increase ($P < 0.05$) from day 12 to day 14. These results were similar to Sebranek et al. (2004) and Lee et al. (2010), who reported that TBARS values increased with time in fresh pork sausages. Conversely, Sebranek et al. (2004) and Lee et al. (2010) reported differences in lipid oxidation amongst antioxidant treatments, whereas treatment effects were similar to the control in the current study. Furthermore, in the current study, TBARS values only began increasing after 7 d of simulated retail display, which agrees with Brewer et al. (1991) who reported that in fresh pork sausages TBARS values increased following day 7 of simulated retail display.

Storage period influenced L* (Table 1). The least

Table 1. Least square means (± SEM) for thiobarbituric acid reactive substance (TBARS) absorbancies, colorimeter readings for L*, a*, and b* and calculated discoloration and color saturation by main effect of storage time.

	Display Day						
	2	4	7	10	12	14	P-value
TBARS[1]	0.040 ± 0.0150[a]	0.068 ± 0.0150[a]	0.057 ± 0.0150[a]	0.120 ± 0.0150[b]	0.148 ± 0.0150[b]	0.198 ± 0.0150[c]	< 0.05
L*[2]	54.2 ± 0.22[a]	54.4 ± 0.22[ab]	54.9 ± 0.22[b]	55.6 ± 0.22[c]	56.3 ± 0.22[d]	57.2 ± 0.23[e]	< 0.05
a*[3]	9.7 ± 0.15[a]	8.1 ± 0.15[b]	6.8 ± 0.15[c]	5.2 ± 0.15[d]	4.2 ± 0.15[e]	3.3 ± 0.16[f]	< 0.05
b*[4]	12.5 ± 0.15[a]	12.2 ± 0.15[a]	11.1 ± 0.15[b]	11.7 ± 0.15[c]	11.1 ± 0.15[b]	10.7 ± 0.15[b]	< 0.05
a*/b*[5]	0.78 ± 0.011[a]	0.67 ± 0.011[b]	0.62 ± 0.011[c]	0.46 ± 0.011[d]	0.37 ± 0.011[e]	0.30 ± 0.011[f]	< 0.05
Chroma[6]	15.8 ± 0.18[a]	14.7 ± 0.18[b]	13.0 ± 0.18[c]	12.8 ± 0.18[c]	11.9 ± 0.18[d]	11.2 ± 0.19[e]	< 0.05
Hue angle[7]	52.2 ± 0.488[a]	56.5 ± 0.493[b]	58.4 ± 0.488[c]	65.7 ± 0.488[d]	69.4 ± 0.488[e]	73.1 ± 0.505[f]	< 0.05

[1]Absorbancies at 530 nm
[2] Black = 0; White = 100
[3] Green = -a; Red = +a
[4] Blue = -b; Yellow = +b
[5] Larger value indicates more redness and less discoloration.
[6] Larger value indicates more saturation of principle hue.
[7] Larger value indicates less red and more discoloration.
[a,b,c,d,e,f] Means within row lacking a common superscript differ ($P < 0.05$)

Table 2. Least square means (± SEM) for interaction of treatment with storage time for colorimeter readings L*, a*, and b*.

	Display Day					
	2	4	7	10	12	14
L*[1]						
Control[x]	^{g}54.8 ± 0.38^{a}	54.8 ± 0.38^{a}	54.9 ± 0.38^{a}	^{g}56.2 ± 0.38^{b}	56.7 ± 0.38^{b}	57.2 ± 0.42^{b}
Trt-1[y]	^{gh}54.5 ± 0.38^{a}	54.2 ± 0.35^{a}	55.2 ± 0.38^{ab}	^{g}55.9 ± 0.38^{b}	56.2 ± 0.38^{b}	57.7 ± 0.38^{c}
Trt-2[z]	^{h}53.5 ± 0.38^{a}	54.2 ± 0.42^{ab}	54.5 ± 0.38^{ab}	^{h}54.7 ± 0.38^{b}	56.0 ± 0.38^{c}	56.8 ± 0.38^{c}
a*[2]						
Control[x]	^{g}10.5 ± 0.26^{a}	^{g}8.9 ± 0.26^{b}	^{g}7.4 ± 0.26^{c}	5.5 ± 0.26^{d}	3.9 ± 0.26^{e}	3.1 ± 0.29^{f}
Trt-1[y]	^{h}9.5 ± 0.26^{a}	^{h}7.8 ± 0.24^{b}	^{h}6.5 ± 0.26^{c}	5.0 ± 0.26^{d}	4.2 ± 0.26^{e}	3.1 ± 0.26^{f}
Trt-2[z]	^{h}9.2 ± 0.26^{a}	^{h}7.6 ± 0.26^{b}	^{h}6.5 ± 0.26^{c}	5.1 ± 0.26^{d}	4.4 ± 0.26^{e}	3.6 ± 0.26^{f}
b*[3]						
Control[x]	12.4 ± 0.26^{a}	^{g}11.8 ± 0.26^{ab}	^{g}10.5 ± 0.26^{c}	11.4 ± 0.26^{b}	^{g}10.3 ± 0.26^{c}	^{g}9.9 ± 0.28^{c}
Trt-1[y]	12.5 ± 0.26^{a}	^{gh}12.1 ± 0.24^{ab}	^{g}11.0 ± 0.26^{c}	11.6 ± 0.26^{bc}	^{h}11.1 ± 0.26^{cd}	^{h}10.8 ± 0.26^{d}
Trt-2[z]	12.6 ± 0.26^{a}	^{h}12.6 ± 0.28^{a}	^{h}11.7 ± 0.26^{b}	12.0 ± 0.26^{ab}	^{i}12.0 ± 0.26^{ab}	^{h}11.5 ± 0.26^{b}

[1] Black = 0; White = 100
[2] Green = -a; Red = +a
[3] Blue = -b; Yellow = +b
[a,b,c,d,e,f] Means within row, within a colorimeter category, lacking a common superscript differ ($P < 0.05$)
[g,h,i] Means within column, within a colorimeter category, lacking a common superscript differ ($P < 0.05$)
[x] Control = 1.8% corn syrup
[y] Trt -1 = 1.8% sweet sorghum syrup
[z] Trt – 2 = 3.6% sweet sorghum syrup

Table 3. Least square means (± SEM) for interaction of treatment with storage time for colorimeter readings a*/b* ratio, chroma, and hue angle.

	Display Day					
	2	4	7	10	12	14
a*/b* ratio[1]						
Control[x]	^{g}0.85 ± 0.019^{a}	^{g}0.76 ± 0.019^{b}	^{g}0.71 ± 0.019^{b}	^{g}0.50 ± 0.019^{c}	0.38 ± 0.019^{d}	0.32 ± 0.020^{e}
Trt-1[y]	^{h}0.76 ± 0.019^{a}	^{h}0.64 ± 0.017^{b}	^{h}0.59 ± 0.019^{c}	^{h}0.44 ± 0.019^{d}	0.38 ± 0.019^{e}	0.28 ± 0.019^{f}
Trt-2[z]	^{h}0.73 ± 0.019^{a}	^{h}0.60 ± 0.020^{b}	^{h}0.56 ± 0.019^{b}	^{h}0.43 ± 0.019^{c}	0.36 ± 0.019^{d}	0.31 ± 0.019^{d}
Chroma[2]						
Control[x]	16.2 ± 0.31^{a}	14.8 ± 0.31^{b}	12.8 ± 0.31^{c}	12.7 ± 0.31^{c}	^{g}11.1 ± 0.31^{d}	^{g}10.3 ± 0.34^{d}
Trt-1[y]	15.7 ± 0.31^{a}	14.4 ± 0.29^{b}	12.8 ± 0.31^{c}	12.7 ± 0.31^{c}	^{gh}12.0 ± 0.31^{cd}	^{h}11.2 ± 0.31^{d}
Trt-2[z]	15.6 ± 0.31^{a}	14.7 ± 0.34^{a}	13.5 ± 0.31^{b}	13.1 ± 0.31^{b}	^{h}12.8 ± 0.31^{bc}	^{h}12.1 ± 0.31^{c}
Hue angle[3]						
Control[x]	^{g}49.8 ± 0.846^{a}	^{g}53.1 ± 0.846^{b}	^{g}55.0 ± 0.846^{b}	^{g}63.8 ± 0.846^{c}	69.4 ± 0.846^{d}	72.4 ± 0.928^{e}
Trt-1[y]	^{h}53.0 ± 0.846^{a}	^{h}57.5 ± 0.784^{b}	^{h}59.5 ± 0.846^{b}	^{h}66.4 ± 0.846^{c}	69.5 ± 0.846^{d}	74.2 ± 0.846^{e}
Trt-2[z]	^{h}53.8 ± 0.846^{a}	^{h}59.0 ± 0.928^{b}	^{h}60.8 ± 0.846^{b}	^{h}66.9 ± 0.846^{c}	69.3 ± 0.846^{d}	72.7 ± 0.846^{e}

[1] Larger value indicates more redness and less discoloration.
[2] Larger value indicates more saturation of principle hue.
[3] Larger value indicates less red and more discoloration.
[a,b,c,d,e,f] Means within row, within a colorimeter category, lacking a common superscript differ ($P < 0.05$)
[g,h] Means within column, within a colorimeter category, lacking a common superscript differ ($P < 0.05$)
[x] Control = 1.8% corn syrup
[y] Trt -1 = 1.8% sweet sorghum syrup
[z] Trt – 2 = 3.6% sweet sorghum syrup

($P < 0.05$) and greatest ($P < 0.05$) lightness (L*) values were observed on days 2 and 14 of display, respectively (Table 1). Moreover, fresh pork patties became lighter (increased L* values; $P < 0.05$) between days 7 and 14 of display. There was a day x treatment interaction ($P < 0.05$) (Table 2). Pork patties formulated with 3.6% sorghum syrup (Trt-2) were darker (lower L* values; $P < 0.05$) than patties formulated with corn syrup (Control) on day 2 of display, and were darker ($P < 0.05$) than patties from the Control and Trt-1 groups on day 10 of display (treatment x display day, $P < 0.05$; Table 2). Otherwise, L* values did not differ ($P > 0.05$) among treatments after 4, 7, 12, or 14 d of simulated retail display. Because there was not a consistent difference in L* values, the difference seen in darkness could potentially be attributed to the fact that the sweet sorghum syrup, by itself, had a darker color than the corn syrup before it was included into the sausage. Considering that sweet sorghum syrup has a darker color than corn syrup, and that no treatment was consistently darker throughout the trial, the data would indicate that the sweet sorghum syrup would need to be included at a concentration greater than 3.6% to produce fresh sausage patties darker than those formulated with corn syrup.

The redness (a*) of the patties decreased ($P < 0.05$) each day of simulated retail display, regardless of treatment (Table 1). These results were similar to a study that evaluated fresh pork patties in aerobic packaging where the researchers reported a decrease in a* values from day 3 to 14 of display (Ahn et al., 1998). The decrease in a* values over time was also reported by Hur et al. (2003) when evaluating fresh ground beef patties made from beef that received dietary conjugated linoleic acid as a means to increase antioxidants in the muscle tissue. Comparison of the treatments (Table 2), the corn syrup (Control) was redder ($P < 0.05$) on days 2, 4 and 7 than 1.8% and 3.6% sorghum syrup, with all treatments being similar ($P > 0.05$) in redness after day 7. The lack of differences in a* amongst treatments following day 7 could potentially be attributed to the increase in lipid oxidation (Table 1) following day 7, as oxymyoglobin oxidation has been reported to be enhanced by lipid oxidation (O'Grady et al., 2001). However, starting on day 10 of the retail display, the fresh pork sausages were not adversely affected by the addition of the sweet sorghum syrup, because they maintained the same ($P > 0.05$) red color as the corn syrup.

Yellowness (b*) values were greater ($P < 0.05$) in patties displayed for 10 d, or more, than patties displayed for 2 and 4 d (Table 1). Interestingly, b* values increased (more yellow color, $P < 0.05$) from day 7 to 10 and subsequently decreased (less yellow color, $P < 0.05$) between day 10 and days 12 and 14. A decrease in b* over the storage period was expected as Scramlin et al. (2010) reported a decrease in b* in beef muscles treated with the antioxidant oregano oil during the retail display storage times of 0, 4, 7, and 11 days. Moreover, Scramlin et al. (2010) reported a statistical difference in b* values for each time period, which contradicts the change in b* values observed between 7 and 12 d of display in the present study. Similarly, Brewer et al. (1991) evaluated sodium lactate in fresh pork sausages and reported that b* values decreased through day 7 and remained constant through the end of the 21-d study. There was a difference ($P < 0.05$) for b* amongst treatments in the current study. Control had a lower ($P < 0.05$) b* value (11.0 ± 0.11) compared to Trt– 2 (12.1 ± 0.11).

All treatments started the 14-day period with the similar ($P > 0.05$) purity of chroma, and all treatments remained the similar ($P > 0.05$) through day 10 (Table 3). There was a day effect as chroma decreased ($P < 0.05$) daily, except for days 7 and 10 (Table 1). When evaluating day x treatment interaction, both the Control and Trt-1 had a decrease ($P < 0.05$) in purity of chroma after day two, however Trt-2 did not see a decrease until after day four. This would indicated that the addition of 3.6% sweet sorghum syrup caused the fresh pork sausages' color to remain saturated for a longer period of time. Additionally, the higher inclusion of sorghum syrup (Trt-2) had less significant ($P < 0.05$) changes in chroma value than both Control and Trt-1.

According to AMSA (2012) color guidelines, reductions in a*/b* ratios indicate more discoloration and loss of redness. It has been reported that the discoloration associated with a*/b* ratios is a result of oxidation and the subsequent conversion of surface color from oxymyoglobin to metmyoglobin (Mancini and Hunt, 2005). Throughout the duration of fresh meat display, the a*/b* ratio should decrease, and the surface color of the meat product will appear discolored. In the current study, each day the a*/b* decreased ($P < 0.05$) (Table 1). There was a difference ($P < 0.05$) amongst treatments in the current study. Control had less ($P < 0.05$) discoloration (0.58 ± 0.008) compared to Trt-1 (0.52 ± 0.008) and Trt-2 (0.50 ± 0.008). Treatment-1 had continuous discoloration throughout the storage period as signified by each time period having decreased ($P < 0.05$) a*/b* ratio values compared to the previous day measurement (Table 3). The Control and Trt-2 decreased ($P < 0.05$) at the same rate, except from day 12 to 14 where Control had less ($P < 0.05$) discoloration on day 14 compared to Trt-2 ($P > 0.05$). The Control had less ($P < 0.05$) discoloration (larger a*/b* ratio values) than Trt-1 and Trt-2 from day 2 to day 10 with all treatments having similar ($P > 0.05$) a*/b* ratio values on day 12 and 14.

Hue angle is a measure of the change in color from the true red axis (0^o) and the true yellow axis (90^o), and the lower the hue angel indicates a redder colored sausage patty. Hue angle increased ($P < 0.05$) daily (Table 1), and there was a difference ($P < 0.05$) amongst treatments for hue angle. Control had a more intense ($P < 0.05$) color (60.6 ± 0.351) compared to Trt-1 (63.3 ± 0.341) and Trt-2 (63.7 ± 0.351). In agreement with a* results, patties formulated with corn syrup (Control) had lower ($P < 0.05$) hue angles than patties formulated with sweet sorghum syrup (Trt-1 and Trt-2) on days 2, 4, 7, and 10 of simulated display, but hue angels were similar ($P > 0.05$) among treatments on days 12 and 14 of display (treatment x display day, $P < 0.05$).

CONCLUSION

The inclusion of sweet sorghum syrup into fresh pork sausages patties did not reduce oxidation as hypothesized because there was no difference ($P > 0.05$) in lipid oxidation, measured using TBARS methods, amongst the treatments. Thus, sorghum syrup would not be considered a multifunctional ingredient, just merely a sweetener when added to fresh pork sausages at the concentration of 3.6%. Additional studies including higher concentrations and different varieties of sweet sorghum would need to be explored to fully understand if sorghum syrup has potential as an antioxidant in meat products. The dark color of sorghum syrup needs to be considered when including sorghum syrup at higher concentrations than 3.6% as the results of this study indicated that sweet sorghum syrup inclusion resulted in more discoloration (a*, a*/b* ratio, and hue angle) than corn syrup through the first seven days of retail display.

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