Fresh Meat Packaging: Consumer Acceptance of Modified Atmosphere Packaging including Carbon Monoxide

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ABSTRACT

Consumers’ perceptions and evaluations of meat quality attributes such as color and shelf life influence purchasing decisions, and these product attributes can be affected by the type of fresh meat packaging system. Modified atmosphere packaging (MAP) extends the shelf life of fresh meat and, with the inclusion of carbon monoxide (CO-MAP), achieves significant color stabilization. The objective of this study was to assess whether consumers would accept specific packaging technologies and what value consumers place on ground beef packaged under various atmospheres when their choices involved the attributes of color and shelf life. The study used nonhypothetical consumer choice experiments to determine the premiums that consumers are willing to pay for extended shelf life resulting from MAP and for the “cherry red” color in meat resulting from CO-MAP. The experimental design allowed determination of whether consumers would discount foods with MAP or CO-MAP when (i) they are given more detailed information about the technologies and (ii) they have different levels of individual knowledge and media exposure. The empirical analysis was conducted using multinomial logit models. Results indicate that consumers prefer an extension of shelf life as long as the applied technology is known and understood. Consumers had clear preferences for brighter (aerobic and CO) red color and were willing to pay $0.16/lb ($0.35/kg) for each level of change to the preferred color. More information on MAP for extending the shelf life and on CO-MAP for stabilizing color decreased consumers’ willingness to pay. An increase in personal knowledge and media exposure influenced acceptance of CO-MAP negatively. The results provide quantitative measures of how packaging affects consumers’ acceptance and willingness to pay for products. Such information can benefit food producers and retailers who make decisions about investing in new packaging methods.

Meat packaging protects the product from deteriorative environmental elements, enables producers to offer meat products in many shapes and sizes in an attractive and hygienic way, offers consumers convenience in terms of ease of use and time savings, and is used to communicate with consumers (38). The market share of fresh meat case-ready packages continues to grow and currently represents 64% of the U.S. fresh meat self-service case. The red meat product most often packaged as case ready is ground beef, with 67% of this product marketed in that form (13).

Numerous case-ready systems integrate modified atmosphere packaging (MAP) (22). MAP involves the replacement of air in the headspace of the packaging with a single gas or a mixture of gases, such as high oxygen (O2) atmospheres with a minimum of 60% O2 (22, 28), or blends of O2 with carbon dioxide (CO2), and is used primarily to extend the shelf life of food products. MAP also can preserve meat color, in particular by including carbon monoxide (CO) in concentrations of 0.3 to 0.5%. CO binds strongly to myoglobin to form carboxymyoglobin and results in a stable bright red muscle color that better satisfies consumers’ color demands. MAP with low concentrations of CO (CO-MAP) and high concentrations of CO2 can improve beef and pork color (37). In 2004, the U.S. Food and Drug Administration approved the use of CO in consumer-ready fresh meat packaging (34, 35). The use of low (<0.4%) concentrations of CO in a packaging system is classified as a generally recognized as safe (GRAS) technology and currently is in commercial use in the United States.

The success of retail MAP formats depends on both product and package attributes that benefit processors and retailers and consumer acceptance of the respective product format (6). From the perspective of the consumer, MAP provides advantages that include increased shelf life and, with the addition of CO, stable and attractive color. Several perceived disadvantages must be weighed against the consumer’s favorable perceptions of MAP. One disadvantage of MAP is the perception held by consumer advocacy groups that food safety may be compromised, in particular by CO-MAP. Although spoilage and pathogenic bacteria are generally reduced by using MAP with increased levels of
CO₂ and/or removal of O₂ (28), several consumer groups have expressed concern that the use of CO-MAP deceives consumers and potentially harms consumers’ health because the color of the meat can mask spoilage (11, 17, 26). These groups have argued that CO stabilizes the color of meat longer than the product’s safe shelf life and that consumers may be deceived by the bright red meat color. The possibility remains, though slight, that pathogens such as Listeria monocytogenes could grow, and consumers who do not pay attention to the date of expiration might be at increased risk (5, 24). Some have speculated that consumers could react negatively to the term “carbon monoxide” because they consider this gas to be potentially dangerous (12).

Given the potential for MAP and CO-MAP to improve the profitability of processors and food retailers by extending the useful shelf life of products, an understanding of consumers’ attitudes toward these new technologies is critical to better position the new technologies and build trust and acceptance in the marketplace. Currently, no MAP labeling that would inform consumers about the applied technologies is required on the product at the point of sale in the United States. Under current U.S. regulations, the packaging and protective gases (CO, CO₂, and N₂) have GRAS status, and GRAS substances do not have to be labeled (33). In other countries, e.g., Germany, MAP labeling is mandatory (16) under the German additive regulation (16), which states that an additive of a technological nature does not have to be mentioned on the package but that a protective atmosphere must be labeled.

Consumers’ negative perceptions about new packaging technologies may stem from both a lack of understanding of scientific research and being misinformed about the specific technologies (8). Consequently, technical information on packaging may be needed to help consumers understand the application and safety of the packaging technologies more clearly and would overcome their resistance to new technologies (8). Although many studies on the technological effects and characteristics of MAP have been conducted (2, 7, 10, 19, 20, 27), there has been little assessment of consumers’ preferences and acceptance concerning MAP and CO-MAP (1, 36). Recently, Van Wezemael et al. (36) analyzed acceptance of various packaging technologies among European consumers and found that vacuum packaging was the most accepted packaging technology followed by MAP. Other technologies, including various kinds of additives, were less accepted. In another study, Scandinavian consumers preferred beef steaks packaged without oxygen, which were noted especially for having increased tenderness, juiciness, and flavor (1). However, actual purchase decisions (buying situations) were not evaluated.

The present study was designed to extend the previous literature by including techniques that measure willingness to pay, with study participants (consumers) paying for products with certain attributes including the packaging technology, color, and shelf life. The use of such nonhypothetical consumer choice experiments is designed to (i) assess the premiums consumers would be willing to pay for shelf-life extension and bright red color in meat, (ii) measure consumer response to specific technologies, including the use of MAP and CO-MAP, with the advantage of providing real economic incentive to correctly determine preferences, and (iii) analyze potential effects of consumer knowledge and media coverage on consumer acceptance. We also assessed how consumer reacted when additional information about MAP and CO-MAP was provided. This type of assessment is valuable and should be considered before decisions are made on the permitted use and labeling of MAP and CO-MAP.

This research was designed to answer the following questions:

(i) Do consumers currently prefer extended shelf life and stabilized color of fresh meat without being specifically informed about the packaging technology?
(ii) Will consumers accept MAP for extending the shelf life and CO-MAP for stabilizing the color after being informed about the technology?
(iii) Does personal knowledge and media coverage influence consumer acceptance of MAP and CO-MAP?

We addressed these questions with regard to ground beef by use of a choice experiment that allowed various product attribute combinations. Our hypothesis was that providing information to consumers about packaging technology increases their willingness to pay for increased shelf life and color stability of fresh meat.

**MATERIALS AND METHODS**

Consumer attitudes, willingness to pay for ground beef attributes of color stabilization and shelf-life extension, and willingness to accept specific packaging technologies were analyzed using an assessment method based on nonhypothetical consumer choice experiments. Consumers were asked to make choices between real products, similar to choices made in a supermarket when shopping for food. The objective was to analyze consumer acceptance of meat under MAP and CO-MAP when technical information was communicated. The choices that study participants made concerning these ground beef packages provided data used to evaluate the willingness to pay for the product attributes of color and shelf life. Participants also completed a survey concerning their attitudes and knowledge about the product attributes and their socioeconomic characteristics. The survey provided additional information for assessing consumer responses.

**Sample data.** A consumer choice experiment was conducted at Iowa State University (ISU) in 2007. The consumer group was recruited from the general public through newspaper advertisements, e-mail lists, and leaflets circulated in public places. The potential participants responded by e-mail and telephone to the advertisements. One of the researchers screened the respondents to ensure that they had purchased ground beef at least once during the past year and that they were older than 18 years. The study was reviewed and approved by the ISU Institutional Review Board for Use of Human Subjects. The participant group was restricted to no more than 10% undergraduate students. The convenience sample of participants was split into 10 groups based mainly on time availability, and respondents were accepted until all slots in the respective groups were filled. Each group contained 8 to 12 participants for a total of 106. No interaction between participants was allowed during the survey. Each participant received US$20 as compensation for participation.

During the experimental study, participants were presented with a written questionnaire that was used to determine their
knowledge of shelf life and meat packaging practices and of media reports about MAP and CO-MAP of food. The questions on packaging technologies provided evidence of how well informed participants considered themselves to be about shelf life, meat packaging practices, MAP, CO in food packaging, high-O\textsubscript{2} packaging, and low-O\textsubscript{2} packaging, e.g., “Have you recently heard anything about modified atmosphere packaging in the mass media?” Participants rated each issue on a scale from 1 (no knowledge) to 5 (very knowledgeable). Mass media had covered the topic of MAP and CO-MAP used in meat packaging quite extensively shortly before the survey took place (26). Thus, questions regarding media coverage were included in the survey after the choice experiments: (i) “Have you recently heard anything about modified atmosphere packaging in the mass media?” and (ii) “Have you recently heard anything about carbon monoxide used in packaging for food in the mass media?” Questions were answered with “yes” and “no.” The methods and questions used in our questionnaire are similar to those used previously in related studies (3). The questionnaire was reviewed by faculty in the ISU Department of Communications and was pretested by asking 10 individuals to complete this questionnaire before the formal survey started. We reviewed the responses from the test group and debriefed these individuals about the questionnaire to check for understandability of questions and wording.

**Product under investigation.** The product used for this study was 1-lb (454-g) portions of 85% lean ground beef prepackaged in white foam trays overwrapped with transparent film. The meat came from two sources: a local supermarket (CO-MAP) and the ISU Meat Laboratory. Ground beef with three different color variations was used: (i) light red ground beef packaged at the ISU Meat Laboratory with O\textsubscript{2}-permeable overwrap to permit O\textsubscript{2}-induced fresh meat color development; (ii) brownish red ground beef aerobically packaged at the ISU Meat Laboratory with permeable overwrap and irradiated with 1 kGy to achieve a standardized and consistent metmyoglobin-like brownish red color to represent a meat color that has begun to deteriorate in retail display; and (iii) bright cherry red ground beef in CO-MAP purchased in a local supermarket to represent the bright cherry red color of CO-packaged ground beef.

**Experimental design.** To investigate consumers’ acceptance of meat shelf-life extension and different shades of meat color due to packaging, a series of nonhypothetical choice experiments was conducted applying a survey instrument that has been validated by Alfnes et al. (3). In nonhypothetical choice experiments, participants are required to buy products instead of only indicating their purchase intention. The method, which confronts consumers with a series of purchasing decisions, is an effective mechanism for evaluating consumer acceptance based on consumers’ willingness to purchase individual products and the characteristics of the product (21).

In the design of the choice experiments, participants were asked to make repeated selections across choice sets that included packages with different meat color, labeled shelf life, and price. In our study, a choice set consisted of two product alternatives and a “none of these” alternative, which gave the participants a way to opt out when none of the products met their preferences (Table 1).

The products in the choice sets differed in key attributes (4). The experimental design included three key attributes: price, shelf life, and color. Each attribute had three levels. Table 2 presents the attributes and their levels. The three price levels associated with the various combinations of attributes were selected based on the mean price of 1 lb (454 g) of 85% lean ground beef in the city where the survey took place, the mean price plus one standard deviation, and the mean price minus one standard deviation. The associated shelf life and color levels provided an array of product attributes by presenting three levels for each attribute.

The levels of attributes presented to respondents (i.e., different prices, shelf lives, and colors) differed among choice sets according to an orthogonal fractional factorial design. This design (25) provided a subset of 27 choice sets that were presented to the participants. In a full factorial design, participants are presented with all possible options, i.e., combinations. In our case a full factorial design would entail 729 choices. If participants had to choose among all possible combinations, participant fatigue would likely occur. Thus, we decided to present only certain combinations within a fractional factorial design. For the experimental design, a software package from SAS (Statistical Analysis Systems, Cary, NC) was used to generate those combinations. Although a researcher could pick the combinations, such decisions would be biased. Use of the SAS computer algorithm ensures that each combination theoretically has the same probability of being selected. We chose 27 choice sets from the 729 possible combinations.

During the experiment, each individual participated in three sequenced sessions that were conducted one after another. Each session included nine choice sets (paired alternative selections). Thus, participants made nine choices in each of three sessions for a total of 27 choice sets. All participants evaluated the same choice sets. However, the order of the choice sets differed by session to avoid ordering effects. As a result, not everyone viewed the same choice set in session 2, for example, but did see that choice set in another session. Furthermore, the design was balanced, meaning that the various levels of attributes appeared the same number of times in a session (e.g., six times for the 3-day shelf life, six times for the 5-day shelf life, and six times for the 14-day shelf life).

For each choice set, two consumer packages of ground beef were displayed and labeled alternative A and alternative B. Participants selected their preferred alternative to buy before moving on to the next choice set. The participants could also choose to buy neither of the two presented alternatives.

The three sessions differed in terms of the information provided to the participants at the start of each of the three sessions. The information was read aloud to participants and also shown.

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**TABLE 1. Example of selection provided for one of the choice sets**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>1 lb of ground beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price ($US/lb)</td>
<td>2.85</td>
</tr>
<tr>
<td>Color</td>
<td>Light red (aerobic package)</td>
</tr>
<tr>
<td>Shelf life (days)</td>
<td>3</td>
</tr>
<tr>
<td>I would choose</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

---

**TABLE 2. Attributes and their levels for ground beef packages used in the choice experiments**

<table>
<thead>
<tr>
<th>Level</th>
<th>Price ($US/lb)</th>
<th>Shelf life (days)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.85</td>
<td>3</td>
<td>Light red (aerobic package)</td>
</tr>
<tr>
<td>2</td>
<td>3.05</td>
<td>5</td>
<td>Cherry red (CO package)</td>
</tr>
<tr>
<td>3</td>
<td>3.25</td>
<td>14</td>
<td>Brownish red (aerobic package)</td>
</tr>
</tbody>
</table>
with an overhead projector so that participants could read it for themselves. Before session 1 (S1), participants had no additional information (only price and the hypothetical date of expiration were provided), a situation that mimics the current market situation for most consumers. Before S2, verbal information was provided about meat shelf life, emphasizing the role of MAP in extending product shelf life. Before S3, verbal information about the role of CO in stabilizing color was provided. All information was technical but presented in “layman’s” language and was neutral, without risk or benefit information.

The following information was provided to participants before S2:

Some technologies such as modified atmosphere packaging will extend food products’ shelf-life. Modified atmosphere packaging relies on altering the composition of gases in contact with the food by replacing pure air with a single gas or a mixture of gases such as carbon dioxide. This is then combined with low temperature storage of less than 38 degrees Fahrenheit (3.33 degrees Celsius). Beyond that, the aim of modified atmosphere packaging is to exclude or greatly reduce oxygen levels, to retain the moisture content of the food and to inhibit aerobic microbial growth.

The following information was provided to participants before S3:

Red meat products are somewhat like sliced apples. Their color can change rapidly—even though the product is still safe and wholesome. In fact, retail stores often discount red meat products that have changed color but are still safe and wholesome—and well within their shelf-life. When products become unmarketable purely on the grounds of cosmetic reasons during their regular shelf-life, this can add costs to the supply system, which in turn can raise meat prices. Modified atmosphere packaging can stabilize the color of ground beef—in addition to extending the shelf-life. Modified atmosphere packaging includes different mixtures of gases, for example with high or low oxygen levels. By eliminating the oxygen from the package and adding minute amounts of the gas carbon monoxide along with other protective gases to the headspace of the red meat packages, products like ground beef can maintain their appealing red color throughout their shelf-life. Thus, they do not lose their marketability. Carbon monoxide systems for meat have been available for approximately four years. To put it in a nutshell, carbon monoxide is a color stabilizer that maintains the typical red color of fresh meat when the gas mixture is applied to the package.

For S1, all ground beef packages were labeled with price and shelf-life information. For S2, the same ground beef packages were again labeled with price and shelf life, but the information “modified atmosphere packaging” was added to those labeled as having a 14-day shelf life. This change in labeling was made to test consumer acceptance of the technology after they were informed about the use of the MAP technology. During S3, all ground beef packages were labeled with price and shelf life, and the packages with cherry red ground beef were labeled “modified atmosphere packaging with carbon monoxide,” again to test consumer acceptance of the technology after being informed about the use of CO. For example, in S1, a particular ground beef package might have had bright red aerobic color, had a 14-day shelf life, and cost US$3.05. In S2, this ground beef package would carry an additional label: “modified atmosphere packaging.”

To summarize, each session included nine choice sets, each with two packages of ground beef displayed. The ground beef package pairs had different combinations of the attributes studied (shelf life, color, and price). Each participant made nine selection choices in each of the three back-to-back sessions (the three sessions took place in one setting; hence, each individual participated in all three sessions). Consequently, each participant made 27 choices in total. Participants were asked which of the two alternative packages presented as a pair they preferred to buy. Also, they could choose to buy neither of the two alternatives. After the participant made the final selection in S3, 1 of the 27 choice sets was drawn randomly for each participant. The product chosen in this choice set was the one to be actually purchased. Because each participant was required to buy one of their selected packages at the end of the experiment, this study is a nonhypothetical experiment designed to induce real economic behavioral responses.

In reality, when the sessions were completed, each participant was given a coupon for ground beef that could be redeemed at a local supermarket because the ground beef packages used in the experiments had been kept at room temperature for variable amounts of time during the course of the experiment.

Before beginning the experiment, participants were informed that they would have the opportunity to purchase at their own expense a maximum of one package of ground beef. The three sessions in one setting took on average 50 min, and the product selections took about 25 min of this time. We have no evidence that participants experienced choice fatigue; each session was prefaced by providing information relevant to the session (e.g., information on the use of MAP).

Statistical methods. Correlation analysis was applied to the survey data on consumers’ knowledge about packaging practices. Statistical analysis of the experimental study data made use of three multinomial logit models (18) to evaluate consumer acceptance of shelf-life extension and color stabilization due to MAP and CO-MAP as identified in this study. The multinomial logit regression is appropriate when the dependent variable is nominal and consists of more than two non-ordered categories; it allows the calculation of willingness to pay for individual attributes.

The unit of observation was the individual participant, and the data were individual specific; each independent variable has a single value for each individual, i. For our study, the data for each individual consisted of information on the ground beef choice (0 = “none of these” alternative, 1 = alternative A, 2 = alternative B) and the regressors: price, shelf-life, color, having heard of MAP and CO-MAP in the mass media, and being knowledgeable about MAP and CO-MAP.

The estimated model for ground beef choice follows Greene (18). In this case,

\[
\text{Prob}(Y_i = j) = \frac{e^{\beta_j x_i}}{\sum_{k=0}^{2} e^{\beta_k x_i}}
\]

for \( j = 0, 1, 2 \), where \( Y_i \) is an outcome of one of the choice sets. The estimated equations present a set of probabilities for the \( j + 1 \) choices for a consumer with characteristics \( x_i \). Eliminating the indeterminacy of the model by normalizing \( \beta_0 = 0 \) yields the following probabilities:

\[
\text{Prob}(Y_i = j|x_i) = \frac{e^{\beta_j x_i}}{1 + \sum_{k=1}^{J} e^{\beta_k x_i}}
\]

for \( j = 0, 2, \ldots, J \) and \( \beta_0 = 0 \). The model implies that we can compute \( J \) log-odds ratios.
### Table 3. Summary of variables used in the analysis of participant choices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>$2.85, $3.15, or $3.25</td>
</tr>
<tr>
<td>Shelf life of 5 days</td>
<td>Dummy variable equal to 1 when ground beef alternative has a 5-day shelf life</td>
</tr>
<tr>
<td>Shelf life of 14 days</td>
<td>Dummy variable equal to 1 when ground beef alternative has a 14-day shelf life; dummy variable 3-day shelf life was dropped due to multicollinearity</td>
</tr>
<tr>
<td>Color</td>
<td>Color of ground beef alternative based on mean a-value (objective redness) of the three levels (light, brownish, and cherry red) measured on the particular day of experiments</td>
</tr>
<tr>
<td>CO color × MassMedia CO</td>
<td>Interaction effect between CO color (dummy variable = 1 when ground beef is cherry red) and MassMedia CO (dummy variable = 1 when individual had recently heard in the mass media about CO and food packaging) ^b</td>
</tr>
<tr>
<td>CO color × Know CO</td>
<td>Interaction effect between CO color (dummy variable = 1 when ground beef is cherry red) and Know CO (categorical variable from 1 [no knowledge] to 5 [very knowledgeable about CO]) ^e</td>
</tr>
<tr>
<td>14-day shelf life × MassMedia MAP</td>
<td>Interaction effect between 14-day shelf life (dummy variable = 1 when ground beef had a 14-day shelf life) and MassMedia MAP (dummy variable = 1 when individual had recently heard in the mass media about MAP) ^d</td>
</tr>
<tr>
<td>14-day shelf life × Know MAP</td>
<td>Interaction effect between 14-day shelf life (dummy variable = 1 when ground beef had a 14-day shelf life) and Know MAP (categorical variable from 1 [no knowledge] to 5 [very knowledgeable about MAP packaging]) ^e</td>
</tr>
<tr>
<td>NOT</td>
<td>Dummy variable equal to 1 when the ‘none of these’ option was chosen for a choice set</td>
</tr>
</tbody>
</table>

^a Two independent variables are interacting when the effect of one of the independent variables differs depending on the level of the other independent variable. To measure this, variables are included as interaction effects. Thus, two independent variables are multiplied to create a new independent variable (the interaction effect). For example, CO color can be multiplied byMassMedia CO to create the variable CO color × MassMedia CO.

^b Question: Have you recently heard anything about carbon monoxide used in packaging for food in the mass media? (yes = 1; no = 0).

^c Question: How knowledgeable do you consider yourself about “carbon monoxide in food packaging”? (1 = no knowledge; 5 = very knowledgeable) (see Fig. 1).

^d Question: Have you recently heard anything about modified atmosphere packaging in the mass media? (yes = 1; no = 0).

^e Question: How knowledgeable do you consider yourself about “modified atmosphere packaging”? (1 = no knowledge; 5 = very knowledgeable) (see Fig. 1).

\[
\ln \left[ \frac{P_{ij}}{P_{jk}} \right] = x'_i(b_j - b_k) = x'_i b_j
\]

if \( k = 0 \). The log likelihood can be derived by defining for each individual \( d_{ij} = 1 \) if alternative \( j \) is chosen by individual \( i \) and 0 if not for the \( J - 1 \) possible outcomes. Then, for each \( i \), one and only one of the \( d_{ij} \) values is 1.

The log likelihood is a generalization of that for the binomial probit or logit model:

\[
\ln L = \sum_{i=1}^{n} \sum_{j=0}^{J} d_{ij} \ln \text{Prob}(Y_i = j).
\]

We used the panel version (18) of the multinomial logit code because each participant gives rise to a group of nine choices in each session. Table 3 gives a summary of the variables included in the analysis.

The willingness to pay is obtained by dividing the coefficients of the respective attribute variable by the negative of the price coefficient. We calculated the marginal willingness to pay as the magnitude of price change required to keep the choice probability constant when the value of the respective variable was changed.

### Results

Table 4 shows the participant and Iowa population characteristics (30–32). There was a relatively high proportion of female participants (77%), fitting the typical shopping demographic. The average age of participants (47 years, the youngest being 19 and the oldest being 83) was somewhat older than the average of the Iowa population. The average household size was between two and three persons (ranging from one to five). This is similar to the state average of 2.4 persons per household. Twenty-three percent of participants had children under the age of 12 in their household. Among the participants, 6% had achieved only a high school degree, which is significantly lower than the state average of 34% of adults with a high school degree as their highest level of education. Hence, the sample includes a significantly higher level of formal education than is representative of the state. As indicated by Table 4, 68% of the sample population had a college degree or higher compared with 25% of the state. The reported household income was typical of the county (49% had income less than the median household income of nearly $50,000).

Results regarding consumers’ knowledge of packaging techniques revealed that participants considered themselves to be more knowledgeable concerning shelf life and meat packaging practices in general than they were about other more specific technologies. They indicated almost no knowledge with regard to specific packaging techniques such as high- or low-O₂ or CO food packaging and relatively little knowledge about MAP (Fig. 1). The correlation analysis revealed that knowledge about meat packaging and shelf life were significantly \((\alpha = 1\%)\) but weakly \((\rho = 0.3\%)\) correlated.

We also investigated whether participants had recently heard anything in the mass media about MAP or about CO used in packaging for food. Sixteen percent of the participants recalled recently hearing or reading about MAP in the mass media, and 21% recalled recently hearing about CO in food packaging in the mass media.
Results from the multinomial logit estimation for S1 through S3 are presented in Table 5. For each session, the first column is the estimated coefficient, the second column is the \( t \) value, and the third is the calculated willingness to pay. The price coefficient in all three sessions was significantly negative, as expected. The higher the price, the less likely the participants were to choose the product.

Results from the multinomial logit models revealed that the respondents indicated no significant (\( p > 0.10 \)) willingness to pay for 5-day shelf life compared with the 3-day shelf life in any of the three sessions. However, the 14-day shelf life had significant coefficients in S2 and S3. This means that in the first session, consumers were not willing to pay for increasing shelf life from 3 days up to 5 or 14 days. However, after introducing information on the MAP technology in S2, the 14-day coefficient became significant. Consumers were willing to pay $0.36 more for the additional shelf life compared with the 3-day shelf life after being informed about the use of MAP technology. In contrast, information on the use of CO in S3 reduced the willingness to pay for the longer shelf-life attribute. The willingness to pay decreased from $0.36 to $0.13 in S3, which is still higher than that in S1 but lower than that in S2.

Results in the three sessions in this study suggest that participants preferred brighter red meat in all three cases as expected. Consumers were willing to pay significantly more for the brighter (aerobic and CO) red color and to add up to $0.16/lb in value for the desirable color. However, introducing information on the use of the packaging technologies led to a reduction in willingness to pay in both S2 and S3 compared with S1. Introducing the respective technologies led to a reduction in willingness to pay for color from $0.16 to $0.11 in S2 and a reduction to $0.05 in S3. Although the amount of money was less, the willingness to pay remained positive.

Individual knowledge and media coverage had little effect on willingness to pay. Among those factors affecting willingness to pay were “knowledge of CO in food packaging” and “having heard about CO in food packaging in the mass media,” both of which had a negative effect on the willingness to pay for CO color.

**DISCUSSION**

The present study incorporated nonhypothetical consumer choice experiments to assess consumers’ willingness to pay for specific meat characteristics (shelf-life extension and bright red color) in meat products and consumer response.

### TABLE 4. Sociodemographics of participants (n = 106)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Result</th>
<th>Standard deviation</th>
<th>Iowa population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (% female)</td>
<td>77</td>
<td>0.42</td>
<td>50.4</td>
</tr>
<tr>
<td>Mean age (yr)</td>
<td>46.6</td>
<td>15.38</td>
<td>39.5</td>
</tr>
<tr>
<td>Mean household size</td>
<td>2.5</td>
<td>1.24</td>
<td>2.4</td>
</tr>
<tr>
<td>Children under 12 yr in the household (% of households)</td>
<td>23</td>
<td>0.42</td>
<td>30.4 (under 18)</td>
</tr>
<tr>
<td>Low education (% of respondents)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>6</td>
<td>0.23</td>
<td>33.7</td>
</tr>
<tr>
<td>Modest education (% of respondents)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some college</td>
<td>16</td>
<td>0.37</td>
<td>21.8</td>
</tr>
<tr>
<td>Technical school diploma and/or Associate’s degree</td>
<td>10</td>
<td>0.31</td>
<td>10.0</td>
</tr>
<tr>
<td>Higher education (% of respondents)</td>
<td></td>
<td></td>
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<tr>
<td>Bachelor’s degree</td>
<td>28</td>
<td>0.45</td>
<td>17.1</td>
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<tr>
<td>Graduate degree (master’s degree or doctorate)</td>
<td>40</td>
<td>0.49</td>
<td>7.9</td>
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<tr>
<td>Household net income (% of respondents)</td>
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<td></td>
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<tr>
<td>&lt;$10,000</td>
<td>5</td>
<td>0.21</td>
<td>6.4</td>
</tr>
<tr>
<td>$10,000–$29,999</td>
<td>21</td>
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<td>17.9 (10,000–24,999)</td>
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<tr>
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<td>23</td>
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<td>27.6 (25,000–49,999)</td>
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<tr>
<td>$50,000–$69,999</td>
<td>18</td>
<td>0.39</td>
<td>20.4 (50,000–74,999)</td>
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<tr>
<td>$70,000–$99,999</td>
<td>19</td>
<td>0.40</td>
<td>12.5 (75,000–99,999)</td>
</tr>
<tr>
<td>$100,000</td>
<td>13</td>
<td>0.34</td>
<td>15.2</td>
</tr>
</tbody>
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* U.S. Census Bureau, 2012 (30).
  
b U.S. Census Bureau, 2012 (31).
  
c U.S. Census Bureau, 2012 (32).

*FIGURE 1. Participants’ perceived knowledge about meat packaging technologies. Mean scores based on a scale of 1 (no knowledge) to 5 (very knowledgeable), n = 106.*


Results confirm that shelf-life extension affects consumers’ willingness to pay for ground beef. Although shelf life had little effect on consumer choices for the shorter shelf life, consumers were willing to pay for the longer 14-day shelf life in S2 and S3. The longer shelf life was preferred after information on MAP was provided. However, the introduction of additional information on the use of CO weakened the respondents’ trust in the MAP technology. Previous research suggested that consumers are not able to completely understand the two MAP options (MAP with or without CO) and make decisions based on trust alone (22). Although some consumers could benefit from the longer storage life, the results suggest that consumers only value the benefit of the applied technology as long as they are knowledgeable and understand it. In this case, CO information seemed to lead to confusion and weaken consumers’ trust. The longer shelf life is only valuable as long as the product is still safe. Because consumers might be prone to judge freshness of ground meat based on its color, thinking that bright red color is fresher and safer could lead to a potential food safety issue. Hence, consumer education needs to focus both on the value of packaging and on encouraging consumers to pay attention to the “best before” date when consuming MAP and CO-MAP products. Consumers’ individual knowledge and their exposure to media coverage did not influence willingness to pay for extended shelf life.

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Color. Maintaining an attractive color in fresh meat during distribution and subsequent display has long been recognized as critically important because color is the first quality attribute consumers use to evaluate meat quality and therefore it plays a major role in influencing purchasing decisions (37). Color has a significant impact on consumers’ quality expectations, even though the color does not affect taste or shelf life (28, 29). Carpenter et al. (9) concluded that consumers were not willing to purchase beef that was not red at the point of sale.

CO-MAP was introduced to the marketplace to stabilize the color of ground beef, and our results confirm that participants preferred brighter red meat color and were willing to pay significantly more for the brighter (aerobic and CO) color. However, introducing information on the use of the packaging technologies led to a reduction in willingness to pay, a result that implies that consumers are sensitive to a technology that affects the meat’s color. Although consumers attribute positive value to the preferred color, providing information about MAP and CO-MAP for packaging affected participants’ choice of ground beef negatively. Consumers’ willingness to pay for attractive color of ground beef declined when MAP or CO-MAP was applied; thus, the use of these technologies decreased consumers’ willingness to pay for color. Consumers’
personal knowledge and media exposure regarding the MAP technologies also affected willingness to pay for ground beef color.

**Limitations.** The nonhypothetical aspect of the study provides a more accurate and comprehensive evaluation of the value consumers place on product attributes. However, in this study, instead of receiving the ground beef itself at the research facility where the study was conducted, participants were given a coupon for their choice of ground beef that could be redeemed at a local supermarket. This is a departure from the strict use of the nonhypothetical choice experimental design and a potential limitation of the study. Nevertheless, the coupon was used because of concern about microbial growth in the fresh ground beef displayed for an extended period of time at room temperature. Although our survey instrument was very close to the real shopping situation when compared with other methods (e.g., written questionnaire without financial transaction), our scenario still does not completely represent real world situations in the marketplace. Although we might expect lower prices because CO-MAP saved costs to retailers, the increase in willingness to pay for products with more desirable attributes may increase demand and outweigh the effect of the reduction in costs. In our study, we allowed for choices where the price might increase or decrease and evaluated the consumer response.

The information provided to participants during the experiments was neutral but highly technical. If this information were to be provided by companies, other communication strategies could influence consumers’ perceptions based on the manner and level of information provided; hence, the outcome in a real market setting might differ from that of our laboratory experiments. Companies may provide information differently, e.g., in a more emotional rather than technical manner. Consumers may perceive information on MAP and CO-MAP differently when provided by the food industry and retailers in contrast to the neutral, technical information provided in this study. Phang and Bruhn (23) found that information on health topics such as food safety is communicated most effectively when provided by both food safety educators and the meat industry together.

**Implications.** Consumers’ acceptance and willingness to pay for new technologies in fresh meat products and packaging have important implications for processors and retailers. Overall, the consumers in this study showed a general lack of knowledge regarding packaging technologies. However, the findings suggest that the information provided to these consumers regarding MAP was sufficient for them to accept the product and pay more for extended shelf life of ground beef, even when informed explicitly about the MAP technology that provides the increased shelf life. In contrast, the results indicate that the information provided to consumers regarding CO-MAP was not adequate to establish a satisfactory level of trust regarding the scientific reliability of CO-MAP options for meat packaging. Although consumers clearly prefer bright red ground beef that results from CO packaging and are willing to pay for the color, their willingness to pay, although positive, decreases when they learn about the use of CO-MAP. The perceived benefits of red color and higher willingness to pay for products dissipate when consumers are informed about the packaging technologies used. Hence, developing clear communication strategies to improve consumers’ education and change (improve) consumers’ attitudes regarding MAP is key. Although a significant number of U.S. consumers accept MAP and CO-MAP, communicating with consumers about the technologies in a clear and unbiased way is vital, as is the trustworthiness of the source of the message (14, 15). However, consumers’ trust in the source of the message was not evaluated here. Information about the use of packaging technologies that are not well understood or may be perceived as involving risky elements can make consumers insecure, which in turn leads to a lower willingness to pay for the product attribute. To facilitate informed decision making about meat purchases, education about these new technologies may best involve communication designed to both educate and inform consumers.

**ACKNOWLEDGMENTS**

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CONSUMER ACCEPTANCE OF CARBON MONOXIDE PACKAGING