Willingness to Pay for PEF-processed Orange Juice: Evidence from an Auction Experiment

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Abstract

This paper presents the results of experimental auctions of the orange juice processed with the pulsed electric field (PEF) technology. A series of experimental auctions are conducted to elicit consumers' willingness to pay (WTP) for the PEF orange juice along with WTP for three other types of orange juice: unprocessed (fresh), thermally processed not-from-concentrate, and thermally processed from-concentrate orange juice. We adopt the second-price sealed-bid auction. With this auction method, the highest bidder claims the product at the price equal to the second highest bid.

The auction results show that unprocessed "fresh" juice had the highest mean bidding price of $2.68/half gallon. The second-highest mean bidding price was for PEF juice at $2.48/half gallon; the third-highest was for not-from-concentrate juice at $1.95/half gallon; and the lowest was for concentrate juice at $1.31/half gallon. The bids were affected by product tasting. The largest change in the mean bidding price occurred to the PEF juice, which dropped after tasting by nearly 17% to become ranked lower than the unprocessed juice

Keywords: Auction Experiment, Pulsed Electric Field, Willingness to Pay, Orange Juice

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Introduction

For marketing a new product, there is no historical market data on quantities, prices, or expenditures available for assessing the demand potential or estimating its demand function. Under this situation, we have to employ different methods for market evaluation. One such approach is the contingent valuation method (CVM) commonly used for assessing consumers' willingness to pay (WTP) for such non-market commodities as clean water or clean air. However, the CVM is based on a consumer survey with hypothetical questions and without real budget constraint. In order to overcome these shortcomings, there has been growing interest in using experimental auction for eliciting the WTP for food safety (Hayes, et al.) or genetically modified foods (Lusk, et al.).

The objective of this study is to elicit the WTP for an orange juice produced by a new technology called the pulsed electric field (PEF) processing. The PEF, as to be described in more detail later, can process fruit juice such as orange juice to preserve its freshness. In order to elicit the WTP for the PEF juice, we can employ the CVM with attempts to describe this new technology in the survey. We recognize that the description of the attributes may affect the outcome of the WTP estimation. For a good such as food and for an attribute such as freshness, the description of an attribute developed by a new technology may not be persuasive unless the consumer has the opportunity to taste the product. For this reason, we employ an experimental auction to obtain the WTP for orange juice produced by the PEF. One of the main objectives is to test whether or not the product tasting alter the consumer's WTP and if so, the WTP with product tasting would be more credible for assessing the market potential for any new food product such as the PEF processed orange juice.

The PEF technology can be applied to all juices such as tomato and apple juice as well as other products such as yogurt and salad dressing. We select orange juice because it is

currently the most consumed fruit juice in the market. The results of our study are useful for the orange industry and the manufacturers of the PEF.

Pulsed Electric Field Processing

The Pulsed Electric Field (PEF) process is a nonthermal process used to inactivate enzymes and microorganisms in liquid food. It was developed primarily to minimize the loss and degradation of food quality attributes that might occur during thermal processing. In the PEF process, the food to be processed undergoes electric field pulses that will destroy the cell wall of enzymes and microorganisms.

The PEF process was first developed in 1960 by a German scientist named Doevenspeck. In 1967, Sale and Hamilton, and Hamilton and Sale published studies of their observations on the cell structure of microorganisms that had undergone a PEF treatment. Subsequent studies examined various potentials of the PEF process, and two main venues of application emerged from this line of research:

(1) Reversible Electroporation, where the cell is given an electric shock in order to transfer DNA to the cell, and

(2) PEF treatment for the inactivation of microorganisms and enzymes.

The basic difference between these two processes is the strength of electric field pulses, which is low in the Reversible Electroporation (5-15 kV/cm) and high in the PEF treatment for food processing (more than 18kV/cm) (Dunn). Although the former has a great potential for scientific research, the latter is more immediate for commercial application with respect to the food industry. Thus, we will study the market potential of the PEF technology as applied to a marketable food product. The current forefront of the latter PEF research focuses on the

physical, chemical, and microbiological effects of PEF treatment of liquid food materials such as orange juice, apple juice, skim milk, yogurt, and eggs.

Among the category of citrus fruit juice, orange juice is the most popular drink in the U.S. market. Freshness is arguably the most important factor in the buying decision of consumers. The thermal process (a.k.a., pasteurization) is currently the industry standard treatment, but it causes an irreversible loss of fresh fruit flavor and various nutrients as well as an undesirable browning in the color of the juice (Yeom et al.; Jia, Zhang, and Min). On the other hand, fresh orange juice has a higher risk of undergoing unfavorable quality degradations as a result of microbiological and enzymatic activities, which might cause adverse health effects upon consumption. Therefore, the PEF orange juice should have a great competitive edge against both unprocessed and pasteurized orange juice because the PEF process destroys microorganisms and enzymes while retaining the flavor compound.

Despite its apparent benefits, the PEF process has not been applied on a commercial basis yet because the information on its process mechanism and its advantages has not been disseminated well, let alone appreciated by the food industry. Hence, a team of food scientists produced the PEF orange juice in the PEF pilot production plant at the Ohio State University (Akdemir Evrendilek et al.). For this purpose, they obtained fresh Valencia oranges, peeled them, homogenized them with a laboratory blender, and then filtered them to remove the pulp. Some of the freshly squeezed orange juice was set aside for comparison in the later consumer evaluation experiment. The remaining orange juice was pumped through the heat exchangers without any heating and then went through the PEF process in the PEF treatment chambers. Upon completion, the PEF orange juice was aseptically packaged in half gallon bottles. Figure 1 illustrates the PEF process in its entirety.

Literature Review

Experimental auction market has been gaining popularity as a method of measuring consumers' willingness to pay for nonmarketed commodities: e.g., food safety (Hayes et al.), meat produced with a genetically engineered growth enhancer (Buhr et al.), and vacuum-packaged beef (Hoffman et al.). In an experimental auction, consumers bid for an auctioned product, and the winner will pay real money for it. This is an advantage over a contingent valuation survey, where no real transactions are involved. As Hoffman et al. note, experimental auction is an especially useful tool for marketers of novel products because it not only measures consumers' acceptance of the product but also yields an endogenously determined market price.[1] Moreover, it can easily incorporate product testing, which is especially useful for food products for which palatability is an important factor (Melton et al.).

There are several auction methods to choose from, but the second-price Vickrey auction has attracted most attention in the estimation of willingness to pay because of its simplicity and its demand-revealing property.[2] Namely, in this auction, each individual's (weakly) dominant strategy is to bid his/her own valuation truthfully under the independent private values assumption (Milgrom and Weber). There is evidence, however, that the participants may not reveal their private values in laboratory experiments. Knetsch et al. cast a doubt on the demand-revealing property of the Vickrey auction by showing the discrepancy between the willingness-to-pay and willingness-to-accept values with regard to a mug cup in a ninth-price Vickrey auction. However, their results do not quite disprove the demand revealing property of the second-price Vickrey auction but rather point out those participants may behave differently if they perceive themselves off the margin or on the margin. Shogren et al. (2001) propose the random nth-price auction with the view to engaging otherwise disengaged participants, but it has

not proved to be a uniformly better method than the second-price Vickrey auction, which is still one of the most attractive auction mechanisms to implement in laboratory experiments.

Nonetheless, it is still worth considering how to motivate off-margin bidders to bid truthfully. To meet this challenge, we consider a multi-product single-unit second-price Vickrey auction, in which four substitute products are sold. In this auction, each participant bids for four competing products simultaneously but is allowed to buy only one of the four products. Because participants can purchase at most one unit of one product, demand reduction predicted in multi-unit auctions is not an issue (for demand reduction in a multi-unit auctions, see List and Lucking-Reiley). With a winner determined for each of the products, each participant has a greater chance of buying a product (i.e., being on-margin) than if there is only one auctioned product. Moreover, the participants are reminded of familiar substitute products, so they can easily obtain a basic idea about appropriate price of the innovative (our focus) product. Thus, a multi-product single-unit auction seems to be a good mechanism to use when the purpose of experiment is to elicit individual private values.[3]

Experimental Design

Each experimental session consists of two stages of repeated auction trials with the binding trial chosen randomly at the end of each stage. Many studies done in the context of estimating willingness to pay for nonmarketed commodities have used repeated trials with one binding trial chosen randomly after all the trials are over (Shogren et al. 1994, Buhr et al., and Hayes et al.). The usual explanation for repeating trials is that participants require market experience to understand that sincere bidding is the dominant strategy (Coppinger, Smith, and Titus) and to realize their true valuation of unfamiliar products (Shogren, List, and Hayes.). The use of repeated trials is, perhaps, not as controversial as the announcement of winning price after each

trial. It is possible that participants do not reveal their true valuations but just respond to the announced prices. Vickrey auction is demand revealing only under the assumption of independent private value, and if the announcement served as a signal, then the independence assumption would be violated. However, we adopted repeated trials because there is no decisive evidence that repeated trials are inconsistent with the demand revealing property, and there is always an option of discarding later trials.

Our design of experimental auction is described as follows. At the beginning of the first stage, the participants receive an identification number and an instruction packet. They are told not to turn the page until instructed to do so or to communicate with other participants. Next, they receive a budget of $3.00 and explanations on the Vickrey auction procedures. Specifically, the monitor conveys the following introduction on the auction procedure:

"Four brand-name candy bars are auctioned off at the first stage. Each participant is asked to sincerely bid for all four candy bars simultaneously as it is in their best interest.[4] The monitor will collect the bids and announces the winner's (i.e., highest bidder's) identification number and the winning (i.e., second highest) bid for each product. If two or more participants are the winners of a product, the monitor will randomly select one of them as the winner. If one participant is the winner of more than one product, then he or she is asked to choose one product to purchase when all trials are completed.[5] For the non-chosen products, the winner will be the next highest bidder who is not the winner of any other product. Thus, there are as many winners as there are products."

The participants then answer a few quizzes to test for their understanding of the rules of auction. The monitor answers all the remaining questions, and the first stage of auction begins.

There are three trials of candy bar auctions, but only one of them is binding (i.e., counts) in order to control for the wealth effect. The binding trial is chosen randomly by the monitor at the end of the first stage. After the binding trial is announced, the winners pay the prices for the products they won. The transactions for the candy bar auction are completed before the beginning of the second stage so that the participants will see how the auction mechanism works before moving on to the second stage. The first stage is precisely the same as the second-stage orange juice auction, except for the fact that the auctioned products are different; the number of trials is only half as many; and there is no tasting. The first stage is designed this way to enhance the level of participants' understanding of our somewhat complicated auction mechanism. Notice, however, that we do not endow the participants with a base product.[6]

At the beginning of the second stage, the participants receive a new identification number and a starting budget of $7.00. They receive the instructions on the auction rules, which are almost the same as in the first stage. Next, they are introduced to the products to be auctioned off. Four kinds of orange juice are auctioned: (1) unprocessed (a.k.a., fresh); (2) PEF-processed; (3) pasteurized, not-from-concentrate; and (4) pasteurized, from-concentrate. The participants receive descriptions of main characteristics of each product and are allowed to inspect the product only visually. In addition, we also design a small poster for each product listing their important attributes. On the instruction sheets, they are asked to answer a few quizzes on the orange juice characteristics. The monitor answers all the remaining questions, and the second-stage auctions begin.

There are a total of six trials of auctions in the second stage.[7] The first three trials collect naïve bids in that the participants must judge orange juices solely on the basis of color, although they may well be familiar with two types of pasteurized orange juice and, to a lesser

extent, unprocessed "fresh" juice. The PEF orange juice has a color similar to the unprocessed juice. After the third trial, the participants are allowed to taste the four types of orange juice. Consumers would not repurchase a product if they do not like its taste. Melton et al. point out the unreliability of willingness to pay measures based on visual inspection only. There are three more trials after the tasting, and the binding trial is randomly chosen out of the six trials. The binding trial is announced and the transactions are completed. Before leaving, the participants are asked to fill out a questionnaire about demographic information, food purchasing behavior, and attitude toward innovative food products.

Results

A total of 27 students at The Ohio State University were recruited to participate in the auction experiments. It is not unusual to use student subjects in economic experiments when the objective is to test hypotheses about market mechanisms and behavior of rational agents. However, as a marketing research tool, economic experiments need to recruit a representative sample of the target population. We hypothesize that willingness to pay for the auctioned products depend on participants' demographic characteristics. In this respect, the use of student subject may be questionable in that they are unlikely to represent the targeted population and that there is not much variation in demographic characteristics. Nonetheless, students are also regular consumers of orange juice so that they may be somewhat representative of consumers in the younger age cohorts. Furthermore, one of our research objectives is to investigate whether or not product tasting will alter the WTP estimation. The results obtained from using student subjects are still useful.

During November 2003, four sessions of the orange juice auctions were conducted in a laboratory located in the Department of Food Science and Technology at The Ohio State

University. Since the PEF processed orange juice was produced in the PEF laboratory and all orange juice products needed refrigeration, it was most convenient to conduct the auction sessions in their laboratory. All the sessions were completed within 90 minutes.

Table 1 and figure 2 present the results from candy bar auction. The comparison of mean bid prices by trial does not reveal any systematic patterns of changes. For example, for Snickers, the mean bid prices decreased from $0.85 in trial 1, to $0.80 in trial 2 and then to $0.75 in trial 3. On the other hand, the bid prices for Toblerone (made in Switzerland) increased from $1.33 in trial 1 to $1.44 in trial 3. The impacts of revealing the winning bid on the subsequent trials are not apparent in this experiment. We note that some participants bid higher than $1.00 for American candy bars; apparently they were not familiar with the candy bar prices. One can buy these candy bars for less than $0.50 from most supermarkets, and they cost $1.00 in the vending machine in the University. Of course, consumers may be willing to pay higher than the store prices if they were very hungry at the auction time. Table 2 presents the overall mean bid prices from the three trials. As expected, the mean bid prices are fairly similar among three American candy bars while the mean price of $1.38 for Toblerone is much higher. Again it may be due to unfamiliarity with Toblerone, this bid price is lower than the price we paid at the store.

Table 3 and figure 3 present the auction results by trial from the orange juice auction. There are six trials conducted with the first three trials being conducted prior to product tasting and three after. Again there appear to be no systematic patterns of changes that we can trace from trial 1 to trial 6. Furthermore, the bid prices for unprocessed and PEF juice are consistently higher than the prices for the not-from-concentrate and from-concentrate juice. Since PEF orange juice looks very much like the fresh juice, our description of the attributes of the PEF juice seems to be persuasive to the participants. Indeed, the bid prices are higher for PEF than unprocessed orange juice for the first three trials prior to product tasting. Note also that the

differences in the bid prices between the not-from-concentrate and from-concentrate orange juices reasonably reflect the retail market situation. Therefore, the participants are very familiar with the orange juice market. This is confirmed by the fact that all participants have consumed orange juice before the experiment.

Table 4 shows the mean bid prices before and after product tasting. Notably, the mean bid price for the PEF juice declines substantially after the product tasting, from $2.71 to $2.25, a 17% drop in the willingness to pay for this new orange juice. After the auctions, we talked to several participants. Some participants said that they did not like the taste of PEF juice, but many others said that it tasted like fresh juice. Also after tasting, the bid price for unprocessed "fresh" juice increases from $2.65 to $2.72. As for the not-from-concentrate and from-concentrate juice, the bid prices did not change much after product tasting. Table 5 presents the overall mean bid prices from all six trials. The results show clearly that consumers are willing to pay more for the PEF orange juice than the widely-consumed orange juice from concentrate and not from concentrate. Overall, consumers are willing to pay $0.53 more for the PEF orange than for not-from-concentrate orange juice. However, consumers do not treat the PEF processed orange juice exactly like the unprocessed fresh orange juice. The sample mean of the individual premiuma for the PEF orange juice with respect to its freshness suggests that the new product is likely to be competitive in the marketplace since the cost of PEF processing should be lower than the mean premium once the PEF technology is adopted on a commercial basis.

Conclusions

This study employed an experimental auction to elicit the willingness to pay for a new orange juice processed with the PEF processing technology. The experiment was designed to auction

four alternative products, which are highly substitutable. However, any participants can only win no more than one product. Even though we conducted six trails for the orange juice auction, only one trial is binding. The second-price Vickrey auction was used for its demand-revealing property.

In the orange juice auction, we sold four orange juices put into exactly the same half gallon containers with the same plain self-adhesive labels. These products are unprocessed fresh juice, PEF juice, not-from-concentrate, and from-concentrate. One important feature of our experiment is that the products for auction are all real products and the attributes of the key PEF orange juice are either visible or detectable with tasting. This is different from other experiments for food safety in which the product attributes are not visible or detectable with tasting. Four sessions of experimental auctions were conducted with 27 participants.

The results show that consumers are willing to pay a premium for the PEF orange juice over both the not-from-concentrate and from-concentrate orange juices. However, consumers also revealed that the PEF juice is inferior to the unprocessed fresh juice. Notably, after tasting the products, the mean bid prices for the PEF juice declined substantially, indicating that some consumers do not like the taste of PEF juice. Nevertheless, the significant premiums for the PEF juice over the pasteurized juices revealed in this study indicate a strong market potential for this new technology in the future.

The most serious limitation of this study is the use of student subjects. In the future, we plan to conduct similar experiments with the general public. The cost of recruiting representative consumers should be substantially higher than is the case with students, but the cost should be still lower than a multicity test marketing program (Hoffman, et al.). In order to explore the true market potential of innovative technology, we believe the cost is worth paying for.

Footnotes

1. Market clearing price is endogenously determined in the popular Vickrey auction, but some auction rule (e.g. the Becker-DeGroot-Marschak mechanism) does not have this feature.

2. Since we only consider single-unit auctions, Vickrey auction and uniform-price auction can be used interchangeably.

3. A problem with this auction is that an inefficient outcome is quite possible. If an individual has higher values for two products, then it is efficient that he buys both of them. However, as soon as this is allowed, we encounter a problem of demand reduction in a multi-unit auction. If demand reduction is present, the individual's valuation of the second unit is less than the true value, and hence the demand revealing property is sacrificed. Our purpose is to elicit true individual values rather than to achieve an efficient outcome or to maximize revenues, so a multi-product single-unit auction does not seem to be a bad institution.

4. We ask participants directly to bid sincerely. This kind of cheap talk may not actually induce participants bid sincerely, but we adopt it anyway because we limit the number of trials, which might be too few for participants to understand the dominant strategy.

5. If a participant is the co-winner of a product and a single winner of another product, then the tie breaking precedes. If the participant is not chosen as the winner of the former product, she is required to buy the latter product unless she is a winner of yet another product.

6. Each participant bids for the products themselves, not for the right to exchange the base product with the target product. For example, Shogren et al. (1994) use the "exchange" format. They use that format because they measure willingness to pay for

food safety, holding other things constant. Hence, it is natural to use the exchange format. In our case, the objective is to observe participants' private values for the product itself, not a particular attribute that it embodies. Moreover, the exchange format requires participants to evaluate two products and calculate the difference in values, which should overshadows whatever benefits we might gain from adopting the exchange format. Thus, we do not endow the participants with a base product.

7. Some authors use 10 to 20 trials because of the empirical observation that bids begin to stabilize after six or seven repetitions (Shogren et al., 1994; Hayes et al.). In our case, participants are assumed to be familiar with the auctioned products to the extent that they can come up with their values for the products. Therefore, we limited the number of repetitions.

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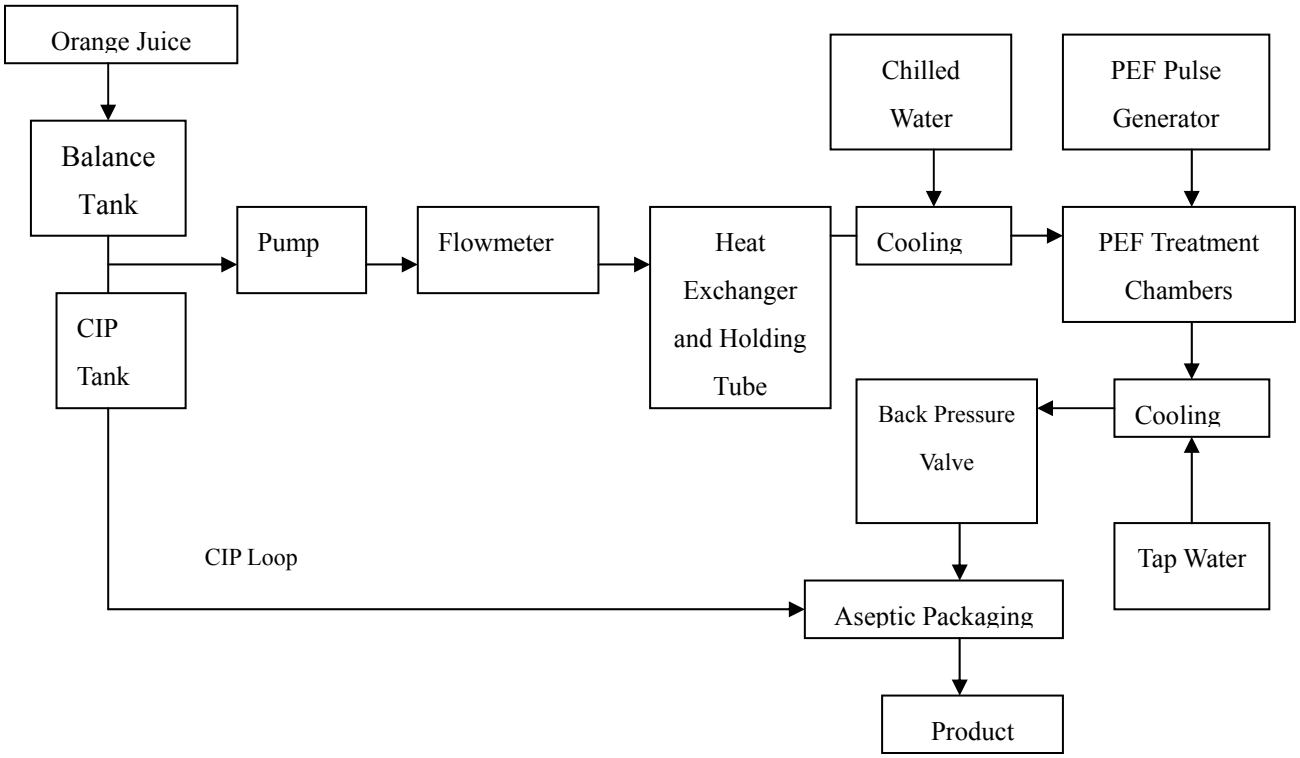

Source: Akdemir Evrendilek et al.

Figure 1. Flowchart of the integrated PEF pilot plant system

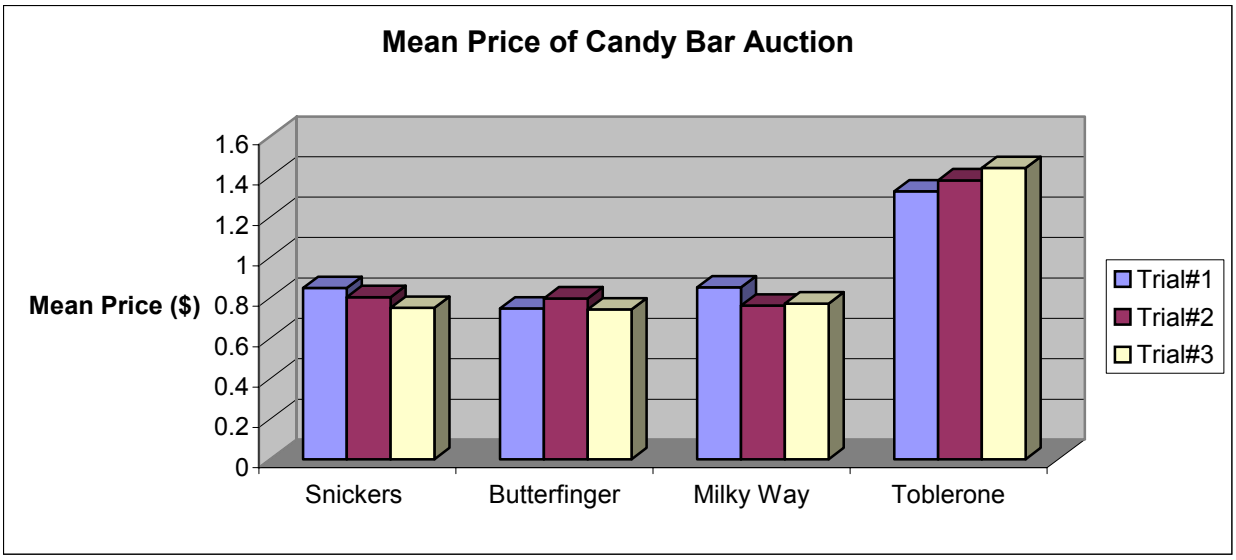

Figure 2. Mean price by trial from candy bar auction

Table 1. Mean Prices from Candy Bar Auction

Product Name	Trial 1	Trial 2	Trial 3
Snickers	$0.85	$0.80	$0.75
Butterfinger	$0.75	$0.80	$0.74
Milky Way	$0.85	$0.76	$0.77
Toblerone	$1.33	$1.38	$1.44

Table 2. Overall Mean Prices from Candy Bar Auction

Product Name	Mean Price
Snickers	$0.80
Butterfinger	$0.76
Milky Way	$0.79
Toblerone	$1.38

Table 3. Mean Prices by Trial from Orange Juice Auction[a]

Orange Juice Product	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Unprocessed "fresh"	$2.57	$2.67	$2.71	$2.80	$2.64	$2.71
PEF	$2.58	$2.71	$2.83	$2.31	$2.25	$2.19
Not from Concentrate	$2.03	$1.98	$1.92	$1.83	$1.96	$1.98
From Concentrate	$1.29	$1.26	$1.26	$1.30	$1.44	$1.33

[a]Prices are in dollars per half gallon.

Table 4. Mean Prices Of Orange Juice Before and After Tasting[a]

Orange Juice Product	Mean Price Before Tasting	Mean Price After Tasting
Unprocessed “fresh”	$2.65	$2.72
PEF	$2.71	$2.25
Not from Concentrate	$1.98	$1.93
From Concentrate	$1.27	$1.36

[a]Prices are in dollars per half gallon.

Table 5. Overall Mean Prices from Orange Juice Auction[a]

Product Name	Mean Price
Fresh	$2.68
PEF	$2.48
Not from concentrate	$1.95
From Concentrate	$1.31

[a]Prices are in dollars per half gallon.

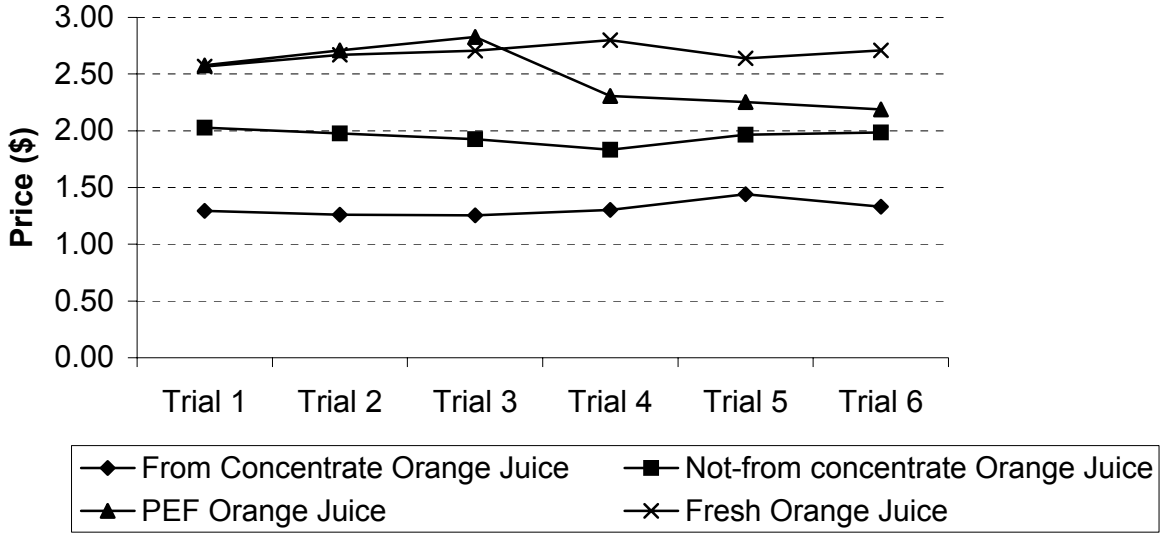

Figure 3. Mean prices by trial from orange juice auction