Pre-meal Beverage Intake Affects Hunger, Satiety, and Energy Intake

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Recent research suggests that an increase in consumption of caloric beverages may contribute to excess weight gain (Malik, Schulze, & Hu, 2006; Wang, Bleich, & Gortmaker, 2008). Several studies have investigated the effects of different caloric beverages on satiety, hunger, fullness, and energy intake and have concluded that consumption of sweetened beverages results in higher total energy intake due to the calories from the beverage (Tordoff & Alleva, 1990; Raben, Vasilaras, Moller, & Astrup, 2002; Monsivais, Perrigue, & Drewnowski, 2007). Additionally, several other studies have investigated the satiating effects of beverages with similar caloric value (Almiron-Roig & Drewnowski, 2003; DellaValle, Roe, & Rolls, 2005; Harper, James, Flint, & Astrup, 2007; Stubbs & Whybrow, 2003). These studies show that the macronutrient composition of the beverage does not have a consistent effect on satiety, nor have there been significant findings in the comparison of total energy intake among the different beverages. These findings are in contrast to those in solid foods, where protein has a greater satiating effect than refined carbohydrates, which has more of an effect than fat (Hill & Blundell, 1990; Rolls, Hetherington, & Burley, 1988; Weigle et al., 2005). Additionally, it is well supported that consuming solid foods that are high in fiber, enhances satiety and decreases energy intake at a subsequent meal (Flood-Obbagy & Rolls, 2009). However, the satiating effects of consuming beverages with added fiber prior to a meal are not well understood. One study by Tiwary, Ward, and Jackson (1997) compared the satiating effects of orange juice to orange juice with added fiber (pectin) and found that the orange juice with fiber significantly increased the self-reported satiety of the subjects for up to four hours. Food intake after consuming the beverage was not measured in this study; therefore, it is not clear how adding fiber to a beverage will impact subsequent energy intake at a meal.

The aim of the current pilot study was to establish whether the addition of fiber to a beverage affects satiety and energy intake at a subsequent meal. If research suggests that consuming a beverage with added fiber increases satiety and decreases subsequent energy intake, than the beverage could be considered a weight management tool.

Methods

Subjects

Students from a mid-sized, midwestern state university were recruited to participate in the study. All potential subjects filled out a screening questionnaire prior to participation. The questionnaire assessed the subject's preference for orange juice, milk, and oatmeal (test meal) and asked them to list any known food allergies. Smokers, competitive athletes, students taking medications affecting appetite, and students dieting to gain or lose weight were excluded from the study. The research was approved by the Institutional Review Board (IRB).

Twenty-five students (20 females and 5 males) were recruited as subjects to participate. Students ranged in age from 19-28 years. After obtaining informed consent, a height and weight measurement was taken for each subject and body mass index (BMI) was calculated.[1]

Experimental design

This experiment used a randomized cross-over design with repeated measures. Following an overnight fast, each subject attended four test meals of oatmeal with one of three beverages consumed as a pre-load or a control of no beverage. Subjects were divided into four groups and assigned standard test meal times on the same day of the week for four weeks. The groups were randomized to ensure the subjects were not all receiving the test beverages in the same order.

Foods and Beverages

The beverages were served cold in 236 mL servings, and included Tropicana Pure 100% Orange Juice[2] and Kemps 1% Milk[3]. Both the orange juice and the 1% milk provided 110 kcals (461 kJ) per 236 mL serving. To test the impact of consuming a beverage with added fiber on satiety and subsequent energy intake, 6 g of wheat dextrin[4] were added to 236 mL of orange juice, which provided 140 kcals (586 kJ). Wheat dextrin is a soluble fiber that does not gel when mixed with a liquid. There is minimal research investigating the satiating effects of added wheat dextrin; therefore, an amount comparable to the 5 g of pectin used by Tiwary, Ward, and Jackson (1997) was selected. Additionally, 6 g of fiber were chosen to prevent gastrointestinal discomfort, which might have led to bias during consumption of the test meals had subjects noticed gas or bloating as a result of the ingestion of fiber.

The test meal consisted of oatmeal made from Quaker Oats[5] sweetened with C&H Pure Sugar Cane golden brown sugar.[6] For 800 g of dry oats, 80 g of brown sugar was added. Subjects were served a large portion (~624 g) and asked to consume the oatmeal until they had initial feelings of fullness. The oatmeal was weighed ($\pm$ 0.01 g) before and after consumption. Energy intake was calculated using the Food Processor SQL software program.[7]

Procedures

The subjects were asked to refrain from alcohol consumption and excessive exercise during the 24-h prior to the test meals. Additionally, subjects were asked to refrain from eating or drinking, using toothpaste, mouthwash, or chewing gum, and exercise the morning of the test meal. When the subjects arrived at the sensory evaluation laboratory they were asked if they followed the pre-study guidelines, and if a guideline was not followed, a note was made. The subjects were assigned to an individual cubical in the sensory evaluation laboratory. When the subjects were not given a beverage (control), they were asked to rate their feelings of satiety,

hunger, and fullness on a 100 mm visual analog scale (VAS) upon arrival. The VAS had opposite extremes anchored at each end of the horizontal line; for example, to assess hunger, the left end stated "I am not hungry at all" and the right end stated "I have never been more hungry." To assess satiety, the anchors were "I am completely empty" and "I cannot eat another bite." To assess fullness, the anchors were "Not at all full" and "Totally full." A ruler was used to measure the millimeters (mm) from the left end of the VAS to the vertical line made by the subject. If a subjected marked a vertical line at the left end of the horizontal line, a value of zero mm was given and if a subject marked a vertical line at the right end, a value of 100 mm was given. After completing the VAS, subjects were given the oatmeal and instructed to eat ad libitum until they experienced initial feelings of fullness. When the subjects received a beverage they were instructed to consume all 236 mL within ten minutes. Once the beverage was consumed, a 30 min timer was set for each individual. At 30 min the subjects were asked to rate their feelings of satiety, hunger, and fullness on a VAS. The oatmeal was then served and the subjects were allowed to eat ad libitum. Once they were finished eating, all subjects rated the palatability of the oatmeal using a VAS.

Data Analysis

Analysis of variance (ANOVA), one-way repeated measures, was the primary statistical test used to determine the significance of the subjective feelings of hunger, satiety, and fullness. Significance was detected using the sphericity-assumed test and pairwise comparisons to identify which variables were significantly different. ANOVA was also used to analyze the significance of intake by weight (g) during the test meals. Results were considered significant at $p \leq 0.05$. A Bonferroni correction was used for post hoc pairwise comparisons of the means. The data were analyzed using SPSS Statistic 17.0, Release 17.0.0 (August 23, 2008).

Results

Subjects

Twenty-five healthy subjects (males, *n*=5; females, *n*=20) participated in the study. One subject was excluded from the study because of missed attendance at the last test meal. The characteristics of the 24 subjects that completed the study are located in Table 1. Fourteen of the subjects were classified as normal weight (18.5-24.9 kg/m^2) and the other ten were classified as overweight (25-29.9 kg/m^2) according to their BMI. All subjects reported that they followed the pre-study guidelines.

Table 1

Subject Characteristics n = 24

Characteristic	Mean ± SE	Range
Age (y)	22.3 ± 0.5	19 – 28
Height (cm)	166.6 ± 2.1	151.2 – 186.7
Weight (kg)	66.9 ± 2.3	51.2 – 92.7
Body mass index (kg/m^2)	24.0 ± 0.6	19.6 – 29.6

Ratings of Hunger, Satiety, and Fullness

Group ratings of hunger, satiety, and fullness are displayed in Figure 1. Thirty minutes after consumption of orange juice with 6 g of fiber, mean ratings of satiety (41.83 ± 20.72 mm) and fullness (37.58 ± 20.18 mm) were significantly higher ($p \leq 0.01$ and $p \leq 0.05$, respectively) compared to the control of no beverage preload (25.19 ± 12.46 mm and 22.25 ± 16.61 mm for satiety and fullness, respectively). The mean ratings of hunger after the consumption of the fiber supplemented juice (47.48 ± 18.49 mm) was significantly lower ($p \leq 0.05$) than the control

(63.00 ± 16.79 mm). There were no significant differences between the other beverages with regards to hunger, satiety, or fullness.

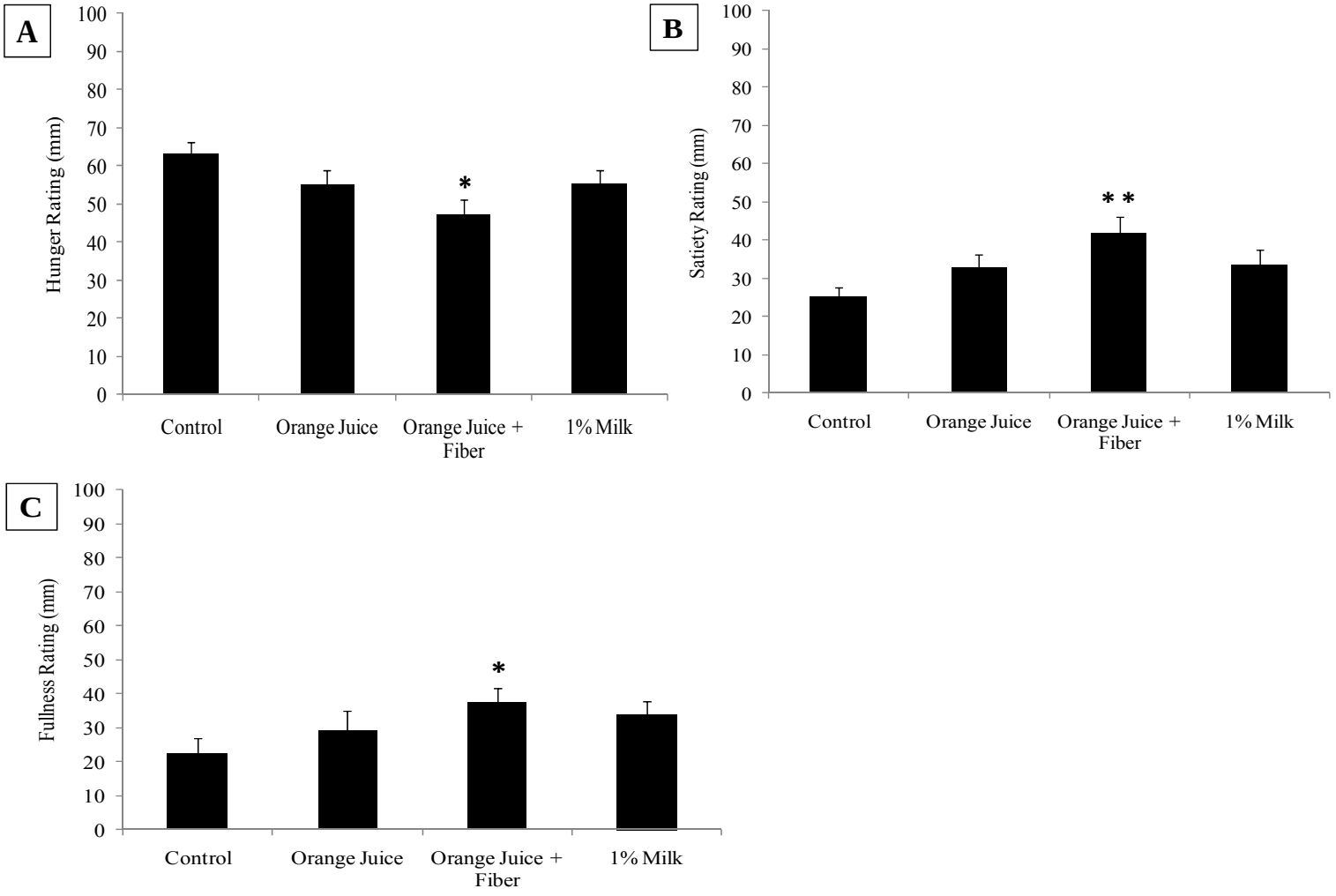

Figure 1. Mean ratings of hunger, satiety, and fullness. After consuming one of three test beverages or no beverage, subjects rated their feelings of hunger (A), satiety (B), and fullness (C) using a 100 mm Visual Analog Scale. The Sphericity Assumed test was used to measure the significance. *$p \leq 0.05$ and ** $p \leq 0.01$ compared to a control of no beverage.

Subsequent Food Intake

As shown in Table 2, there were no differences between the four treatment groups with regards to the gram amount or energy content of the test meal that subjects consumed.

Table 2

Food and Energy Intakes of the Test Meals with and without the Beverage Pre-load Energy Contribution (Mean ± SE)

	Control	Orange Juice	Orange Juice + Fiber	1% Milk
Test meal intake				
Energy (kcal)	476 ± 35	463 ± 35	435 ± 31	444 ± 27
Energy (MJ)	1.99 ± 0.15	1.94 ± 0.15	1.82 ± 0.13	1.86 ± 0.11
Weight (g)	299.9 ± 21.9	292.0 ± 22.3	273.9 ± 19.2	279.8 ± 17.0
Total energy intake (preload + test meal)				
Energy (kcal)	476 ± 35	573 ± 35	575 ± 31	554 ± 27
Energy (MJ)	1.99 ± 0.15	2.40 ± 0.15	2.41 ± 0.13	2.32 ± 0.11
Weight (g)	299.9 ± 21.9	361.0 ± 22.3	362.3 ± 19.2	349.0 ± 17.0

When combining gram weight of the beverage preload with the gram weight of the test meal, there were no significant differences among the four treatment groups (Table 2). Additionally, when the energy content of the beverage preload was combined with the energy content of the test meal, there were no significant differences among the four treatment groups (Figure 2). These data suggest that although the addition of fiber to orange juice increased subjective feelings of satiety (Figure 1), the effect was not dramatic enough to decrease subsequent food intake.

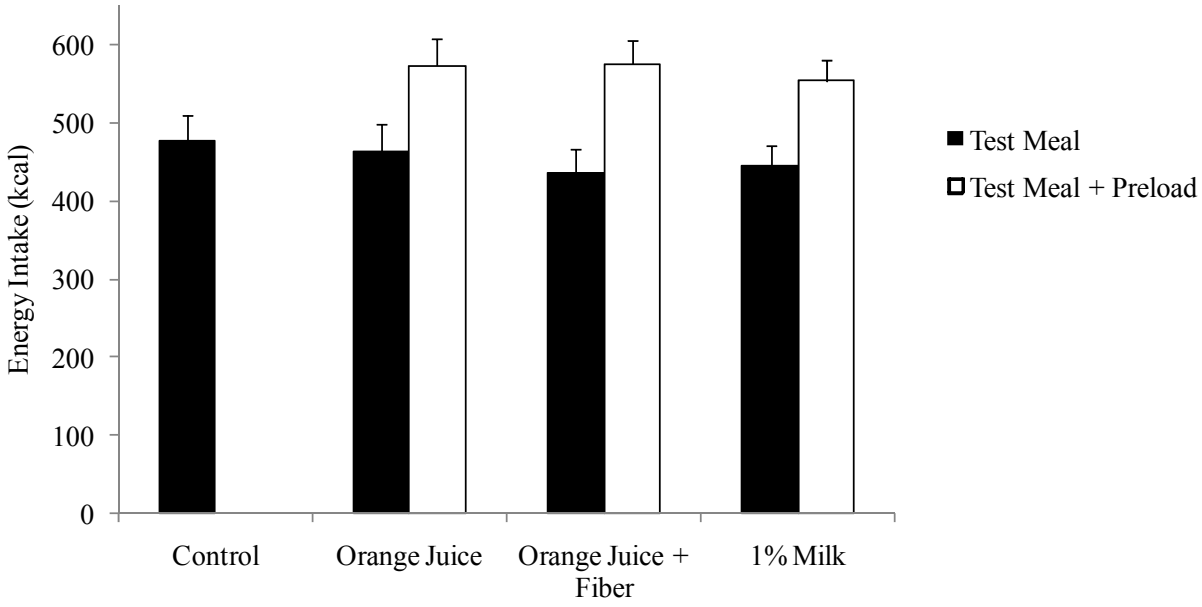

Figure 2. Mean energy intake of test meal and total energy intake. Energy intake of the test meal (filled squares) and total energy intake (test meal + beverage preload, open squares) was calculated using the Food Processor SQL software program (ESHA Research, Salem, OR, USA).

Discussion

Several studies have analyzed the effects of beverages including colas, water, juice, and milk on energy intake, satiety, hunger, and fullness (Almiron-Roig & Drewnowski, 2003; Davy, Dennis, Dengo, Wilson, & Davy, 2008; DellaValle, Roe, & Rolls, 2005; Harper, James, Flint, & Astrup, 2007; Van Walleghen, Orr, Gentile, & Davy, 2007). Based on the review of available literature, there are limited data comparing the effects on satiety and food intake of a caloric beverage with added fiber to other caloric beverages. The current study was designed to analyze the differences in satiety, hunger, fullness, and subsequent energy intake in college-aged students after consumption of a caloric beverage with added fiber. Orange juice, orange juice with fiber (wheat dextrin), 1% milk, or a control of no beverage was given 30 minutes prior to a meal of oatmeal. Before the oatmeal was served, the subjects rated their satiety, hunger, and fullness on a

visual analog scale (VAS). The oatmeal was weighed in grams before and after consumption and the intake was recorded. Compared to the control of no beverage, the orange juice with added fiber statistically increased subjective measures of satiety and fullness and decreased subjects' perceptions of hunger. These increased feelings of fullness and satiety resulted in a decreased subsequent food intake, with the subjects consuming the least amount of oatmeal after the consumption of the juice with fiber; however, these results were not significant.

Based on the results of the current study, it can be concluded that adding a fiber supplement to a beverage will increase subjective feelings of satiety and fullness and decrease hunger compared to a control of no beverage. These findings are similar to those of Tiwary, Ward, and Jackson (1997), who showed that at least 5 grams of fiber (pectin) added to orange juice, significantly decreased hunger and increased satiety. In the present study, increased feelings of fullness and satiety after consuming orange juice with added fiber did not lead to a decrease in subsequent energy intake. These results are in contrast to those of Flood-Obbagy and Rolls (2009), who found when preloads of apple, applesauce, apple juice, or apple juice with added fiber were given prior to an ad libitum meal, subsequent energy intake was significantly lower compared to the control regardless of the type of preload. In the current study, when the energy content of the beverages was factored in, the subjects consumed the least amount of total kilocalories when they were not given a beverage, and the most kilocalories when given orange juice (with or without fiber) as a preload. Therefore, the reduced intake of oatmeal after consuming the orange juice with fiber was not enough to compensate for the higher caloric value of the beverage.

A major difference between the present study and those of Tirwary et al. (1997) and Flood-Obbagy and Rolls (2009), is that both Tirwary et al. and Flood-Obbagy and Rolls used

pectin, while the present study used wheat dextrin. Wheat dextrin is similar to pectin in that it is a soluble fiber; however, wheat dextrin is less viscous and does not gel as readily when mixed with a liquid (Slavin et al., 2009). The less viscous nature of wheat dextrin compared to pectin could partially explain the lack of statistical significance with regards to subsequent food intake. Additionally, a post-hoc sample size calculation indicated a sample size of 46 subjects was needed for an 80% chance of detecting a true difference in energy intake between the beverage variables.

Previous research conducted by Sandhu, El Samahi, Mena, Dooley, and Valenzuela (1987) determined that a dose of 15 grams of pectin fiber added to 400 mL of 10% glucose solution can decrease subsequent energy intake. These authors concluded that pectin increased the viscosity of the meal, which in turn delayed gastric emptying and enhanced feelings of satiety; it is possible that with a larger dose of fiber our subjects may have reduced their energy intake to a greater degree. However, fifteen grams were not used in the current study because of the limited research regarding the gastrointestinal effects of wheat dextrin. Our subjects were blind to the fiber component and a potential threat to validity may have existed if subjects who received the fiber during the first test meal experienced gastrointestinal discomfort.

Orange juice with fiber might promote a higher satiety rating and would result in less subsequent food and energy intake due to fiber's ability to delay gastric emptying through the actions of the satiety hormones pancreatic polypeptide and cholecystokinin (Di Lorenzo, Williams, Hajnal, & Valenzuela, 1988; Kissileff, Pi-Sunyer, Thornton, & Smith, 1981). Another possible explanation for the fiber not showing a significant decrease in subsequent energy intake may be that the 30 minute period between consuming the beverage preload and the test meal was not long enough for the fiber to fully affect the release of satiety hormones. However, it is

important to note that the fiber used in this study, wheat dextrin, has not been extensively studied; therefore, the conclusion that the fiber causes secretion of satiety hormones or a delay in gastric emptying cannot be made with confidence.

Results from the current study suggest that there are no differences in perceptions of hunger, satiety, and fullness between preload beverages of milk, orange juice, and orange juice with fiber. These findings are similar to those of Almiron-Roig and Drewnowski (2003), who found no significant difference in perceptions of hunger, satiety, and fullness between orange juice, 1% milk, and cola. Additionally, DellaValle, Roe, and Rolls (2005) investigated the effects of orange juice, 1% milk, regular cola, diet cola, and water on feelings of hunger and satiety in subjects 18-60 years of age, and found no significant difference in hunger and satiety perceptions between the beverages. Contrary to these findings, Harper, James, Flint, and Astrup (2007) found a 500 mL preload of milk to increase feelings of fullness and decrease feelings of hunger more so than cola. This data confirms that, when consumed in standard serving sizes, beverages do not have a macronutrient hierarchy. However, *trends* from the current study combined with the previous findings of Harper, James, Flint, and Astrup (2007) suggest that a complex carbohydrate (fiber) may have greater effects on satiety than protein (milk), and protein may have a greater effect than the simple carbohydrate (orange juice). More research is needed to confirm if there is indeed a macronutrient hierarchy with regards to satiety in beverages.

The current study has some methodological limitations. One limitation is that the subjects were not asked to rate their feelings of hunger, satiety, and fullness prior to receiving the beverage. Therefore, it is not clear whether there were differences in subjective feelings of hunger prior to consumption of the beverages, which may have impacted the results. However, the subjects were requested to maintain a consistent eating and physical activity pattern 24 hours

prior to the test meals; therefore, it is assumed that the subjects likely had similar levels of hunger from week to week. A second limitation is that when the subjects were not given a beverage, they were not asked to wait 30 min prior to rating their perceptions of hunger, satiety, and fullness. It is expected that if subjects waited an additional 30 min, their feelings of hunger would have increased, and their feelings of satiety and fullness would have decreased. While this may have strengthened our differences in subjective measurements of satiety, fullness, and hunger, waiting an additional 30 min may have caused subjects to consume more of the test meal. Consequently, it is possible that the potential energy intake in the control group that did not receive a beverage was underestimated.

In conclusion, consuming a sweetened beverage with 6 g of added wheat dextrin increases subjective measures of satiety and fullness, and decreases hunger compared to a control of no beverage, but it does not significantly impact energy intake at a subsequent meal. Additional research is needed to determine if a larger dose of wheat dextrin, added to a beverage consumed prior to a meal, decreases overall energy intake and promotes energy balance.

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[1] Model TBF-215GS; Tanita Corporation of America, Inc., Arlington Heights, IL, USA

[2] Tropicana Manufacturing Company, Inc., Bradenton, FL, USA

[3] Kemps LLC, St. Paul, MN, USA

[4] Benefiber®, Novartis Consumer Health, Inc., Parsippany, NJ, USA

[5] The Quaker Oats Company, Chicago, IL, USA

[6] Domino Foods, Inc., Yonkers, NY, USA

[7] ESHA Research, Salem, OR, USA