The NEW ENGLAND JOURNAL *of* MEDICINE

ORIGINAL ARTICLE

A Multicenter Prospective Cohort Study Evaluating the Effect of Temperature on Banana Browning — The Banana Health Study

Kate Humphrey, Brittany Lee, Julia McNabb-Baltar, Karandeep Singh, Neeharika Srivastava, James Yeh, and Jessica Zerillo,
on behalf of the Banana Health Study Investigators *

INTRODUCTION

Bananas, an edible fruit produced by large flowering plants in the genus Musa, are the 3rd most popular fruit consumed in the world and produced in over 120 countries in 5 continents. According to the Fruit and Agricultural Organization of the United Nations database, bananas are the most valuable export commodity in the global fruit and vegetable export market (1). Given their importance and contribution to the world economy, the process and the timing of harvesting and ripening of the fruit to reach the consumer in a timely fashion is of great importance.

The iconic yellow color of the banana is derived from the phenolic compounds contained in the cellular walls of the skin. The process of ripening and browning of a banana is a complex interplay between the environment and the fruit. Certain volatile exposures, such as ethylene gas, physical damage, and exposure to cold (whether natural or a result of refrigeration), may accelerate the process of browning (2, 3). When damaged or exposed to the cold, the cell membranes contained in the banana peels breakdown and leak. As a result, the phenolic compounds mix with polyphenol oxidase leading to the oxidation of the phenolic compounds producing melanin, turning bananas brown. This browning process signifies to the purchaser the optimal time to consume the banana.

Our interest in conducting this study is derived from two motivations. First, the US Department of Agriculture (USDA) has conducted periodic surveys of fruit consumptions of individuals and households in the United States since the 1930s and the Economic Research Service from the USDA has been analyzing the data since 2000 (4). However, little is known about the environment and the median time to browning in the household after the fruit has been purchased.

Second, in recent years, there has been a decline in the number of animals used in research, experimentation, teaching, and testing (5). We believe this trend reflects the fact that animal models for medical research are no longer favored. Most recently, the NIH announced plans to significantly reduce the number chimpanzees for NIH-funded biomedical research (6). Considering these trends, we believe that there is a need to develop new models of disease for research purposes and believe that banana browning has the potential to be an optimal new model for studying ischemic injury in humans. There is some suggestion that bananas may share a fraction of their DNA with humans (see Figure 1).

Figure 1: Bananas May Serve As a Model for Human Disease (Source: Google Images)

Bananas are known to brown quicker at cold temperatures and this may be an ideal model to study the basic mechanisms of frostbite in humans. We hypothesize that banana browning will occur within 48 hours at cold temperatures and will not occur at room temperature.

Here, we present the data from the Banana Health Study (BHS), a prospective multi-centered cohort study examining the association between the household environment and the browning process of bananas.

METHODS

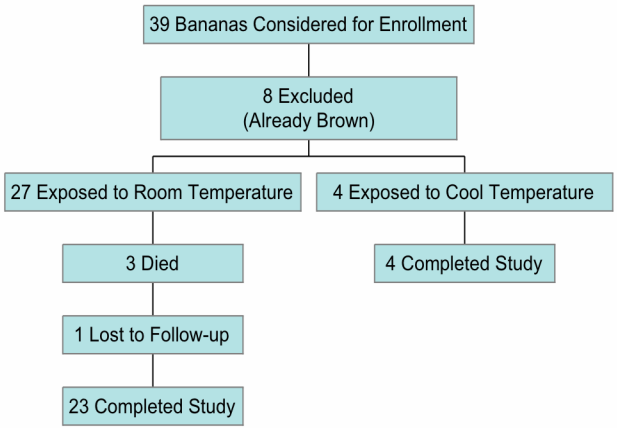
This is a prospective multi-centered cohort study where study subjects were recruited and enrolled from the homes of seven researchers in the 2013 Principle of

* Correspondence may be sent to any of the Epidemiology 208 Instructors or Teaching Assistants.
No financial conflicts of interest to report.

Clinical Effectiveness Epidemiology 208 class. In this study, we examined the time it took for bananas to turn brown when exposed to refrigerated temperatures (defined as standard and normative temperature of a typical household refrigerator or freezer) as compared to the control of keeping bananas on the counter at the ambient temperature of the household.

This is not an interventional study. Bananas exposed to the refrigerator or freezer were already there to begin with or were placed there by non-investigators as part of their natural life cycle (e.g. making of banana bread).

Figure 2: Study Flowchart. Note that exposure groups were not randomized.



Study subjects included non-brown bananas that were kept at room temperature or kept in a cool refrigerated environment. Study subjects that were excluded were bananas that had already turned brown. Subjects who met study inclusion criteria and did not meet study exclusion criteria were enrolled into the study beginning on July 9, 2013.

Enrollment in to the study occurred on a rolling basis during the study period. The primary endpoint to be assessed was the time in hours for each banana to turn brown. The time of the study was limited to a 48 hour time period ending on July 11, 2013 with formal re-evaluation occurring at 24-hour and 48-hour time periods; intermittent evaluations of banana color change were also performed at the discretion of the individual researcher.

Subjects lost to follow-up were followed through interviews with other family, significant others, and friends present in the household of each primary researcher.

Figure 3: (Left): Banana Being Lost to Follow-up, (Right) Banana Facing Imminent Death [competing risk], (Bottom) Banana Turning Brown

RESULTS

In this prospective cohort study, the number of brown bananas observed at room temperature was compared to the number at cold temperature. We found that incidence rate for banana browning at 48 hours was .011148 at room temperature and .028846 at cold temperature.

In short, bananas at cooled temperatures have 2.6 times the rate of color change to brown compared to bananas at room temperature. This finding does support our initial hypothesis that bananas are more likely to turn brown at 48 hours when kept at a cold temperature as compared to room temperature.

Table 1. Exposures

	Browned	Did Not Brown, Lost To Follow-Up, or Death
Cold-exposed (n=4)	3	1
Room temperature (n=27)	10	17

Table 2. Outcomes

	Browned	Banana-hours
Cold-exposed (n=4)	3	104
Room temperature (n=27)	10	897

CONCLUSIONS

Our study does contain multiple confounding factors and bias that we did not consider in the analysis.

Only 4 of the enrolled study subjects were exposed to cold temperatures. Perhaps these bananas were destined to death in the form of banana bread and did not receive the same level of love and support given to bananas that were lying on the counter.

Information on the baseline degree of ripeness of each banana at initial enrollment was not collected and may have affected our results. Also, multiple different banana types were enrolled including different brands, bananas harvested from both organic and conventional farms, different banana species, and different countries of origin.

There are over 70 species of *Musa* of banana species and these differences were not accounted for and may have impacted our findings. The temperature was also not controlled strictly in our study since room and cold temperature was not defined. After the study was performed, the different site leaders reported different banana temperature environments. A portion of the bananas kept at room temperature were in an air-conditioned environment while another portion was stored at ~90 degrees Fahrenheit, the ambient temperature in Boston when the study was conducted. For the cold environment, some bananas were placed in freezer temperatures and others were in fridge temperatures. Also, exposure to other fruits and vegetables were not considered in the study. There is some research in the agricultural literature from the University of Hawaii suggesting that a banana's exposure to other fruits and vegetables, which release ethylene gas, will affect the browning or ripening rate (7). In future studies, ethylene gas levels can be measured with a new sensor developed recently by MIT investigators (8).

Despite the confounding factors in our study, the findings do have value as they indicate that banana browning can develop in a short period of time and is temperature dependent – two factors that make the banana a unique model for biomedical research studies of ischemia. We would like to further pursue this investigational work and perform a blinded randomized control study accounting for the confounding factors. For this study, we plan to submit an NIH grant to support our work, and if this pursuit is unsuccessful, we plan to explore alternative sources of funding including venture capital.

REFERENCES

1. Fruit and Agriculture Organization of the United Nations. 2013 [cited 2013 July 12, 2013]; Available from: http://www.fao.org/wbf/en/
2. Kheng TY, Ding P, Abdul Rahman NA. Determination of optimum harvest maturity and physico-chemical quality of Rastali banana (Musa AAB Rastali) during fruit ripening. J Sci Food Agric. 2012 Jan 15;92(1):171-6.
3. Kulkarni SG, Kudachikar VB, Keshava Prakash MN. Studies on physico-chemical changes during artificial ripening of banana (Musa sp) variety 'Robusta'. J Food Sci Technol. 2011 Dec;48(6):730-4.
4. U.S. Fruit and Vegetable Consumption Who, What, Where, and How Much. October 2004 [cited 2013 July 2013]; Available from: http://ers.usda.gov/media/304397/aib792-2_1_.pdf
5. Kulpa-Eddy JS, Margaret; Stokes, William. A review of trends in animal use in the United States (1972 – 2006). AATEX, Proc 6th World Congress on Alternatives & Animal Use in the Life Sciences. August 21-25, 2007;14(Special Issues):163-5.
6. NIH to reduce significantly the use of chimpanzees in research. 2013 [cited 2013 July 12, 2013]; Available from: http://www.nih.gov/news/health/jun2013/od-26.htm
7. Banana Ripening: Principles and Practice. 2013 [cited 2013 July 12, 2013]; Available from: http://www.ctahr.hawaii.edu/nelsons/banana/ripeningbunchmanagement.pdf
8. Comparing apples and oranges: New sensor can accurately measure fruits' ripeness, helping prevent loss of produce from spoilage. 2012 [cited 2013 July 12, 2013]; Available from: http://web.mit.edu/newsoffice/2012/fruit-spoilage-sensor-0430.html