2017

A literature review of the effects of home and commercial processing methods on nutritional and sensory properties of green beans (phaseolus vulgaris)

Emily Hope Bauman

A Literature Review of the Effects of Home and Commercial Processing Methods on Nutritional and Sensory Properties of Green Beans (*Phaseolus vulgaris*)

Emily H. Bauman

May 2017

Scientific report submitted
to the Davis College of Agriculture, Natural Resources, and Design at
West Virginia University
in partial fulfillment of the requirements for the degree of

Master of Science
In Nutrition and Food Science

Dr. Janet Tou, PhD, Chair
Dr. Nicole Waterland, PhD, Co-Chair
Dr. Youyoun Moon, PhD

Department of Animal and Nutritional Sciences

Morgantown, West Virginia
2017

Key words: green beans, canning, blanching, freezing

ABSTRACT

A Literature Review of the Effects of Home and Commercial Processing Methods on Nutritional and Sensory Properties of Green Beans (*Phaseolus vulgaris*)

Emily Bauman

A comprehensive review of current literature was conducted to investigate nutrient retention, texture and color during processing and storage of green beans. Consumers do not take into consideration of the effects of processing and storage on the nutritional and sensory quality of the green beans. Freezing and canning are the main processing methods used to extend the shelf-life of green beans. Both frozen and canned green beans are blanched during processing. Green beans are either frozen after blanching or for canning undergo additional thermal processing. Ascorbic acid was found to remain stable after steam blanching at 90°C for 3.5 minutes. Freezing green beans for three months at -20°C can cause up to 41.5% of ascorbic acid to be lost while extended frozen storage of six months can cause ascorbic acid content to decrease to 49.6%. Thermally processing canned green beans at 100°C for 20 minutes caused an insignificant effect on the antioxidants ascorbic acid, phenolics and flavonoid content. Canning and freezing also affected green bean texture differently. The texture of frozen green beans remains firmer than canned green beans though both were softer than fresh green beans after 31 days of storage. The color of canned green beans is also affected by blanching and thermal processing. Frozen green beans turned light green after 31 days of storage while canned green beans became a dark green over the same storage period. Overall, for shorter shortage periods of 3-4 months, frozen green beans retain more nutrients as well as had a similar color and texture to fresh green beans. For an extended storage period greater than six months, color and texture of the canned beans do not change from when the green beans are canned. Research regarding home processing methods for green beans will help home gardeners make a more educated choice regarding the type of preservation that will best suit their individual needs. Consumers can also benefit from this research by allowing a more educated decision between commercially or home canned and frozen green beans.

INTRODUCTION

Fresh green beans have a shelf-life of approximately 8-10 days, therefore processing is necessary to extend shelf-life.[2] Commercially, 497,810 tons of green beans were canned and 267,090 tons were frozen in 2015.[3] Additionally, green beans are a common vegetable to can and freeze for home gardeners.[1]

Green beans are a rich source of riboflavin, folate, polyunsaturated fatty acids linoleic acid, α-linolenic acid, phytochemicals and antioxidants such as: ascorbic acid, phenolic compounds, and flavonols.[1, 4, 5] Consumer desirability of green beans is dependent on nutritional value as well as sensory parameters such as: color and texture.[6] Nutrient and sensory losses that occur during processing are important to address to ensure green beans remain nutritious as well as visually and texturally appealing to home gardeners and consumers.[7]

The purpose of processing green beans is to extend shelf-life. Processing to increase shelf-life includes pre-treatment blanching to slow enzymatic reactions which allows green beans to be preserved through freezing and canning (Figure 1).[1] Compared to fresh green beans, blanched green beans lose water-soluble nutrients and undergo texture changes.[8] Home processing of green beans includes canning and freezing. The difference between canning and freezing is the length of time green beans are heated before being safe for storage.[9] The initial home processing is through blanching which lasts three to four minutes at 100°C for frozen green beans, and one to two minutes for canned green beans.[6] Commercially canned green beans require sterilization through thermal processing at 115°C for 15 minutes in a sealed jar.[10]

Due to the basic content (~pH 5.6) of green beans, home canned green beans are pressure cooked at 121°C for 20 minutes in brine (salt water solution) which kills bacteria and botulinum

spores.[11] Home canning sterilization is most successful when the brine is at a pH of less than 4.5. An acidic brine prevents microorganisms from growing in the jar. An acidic brine is achieved by adding salt to the jar prior to pressure cooking. Pressure cooking forms a vacuum seal on the jars to prevent liquid from evaporating as well as to prevent air from entering.[11]

The process of freezing green beans at home differs slightly from the home canning process. Green beans are blanched at 100°C for three to four minutes, then cooled off in an ice bath for three to four minutes immediately after blanching.[11] Despite research on conventional processing methods such as canning and freezing, no studies have addressed the combination of pre-process blanching, freezing, home and commercial canning of green beans for nutritional and sensory parameters within the same study. Therefore, the aim of this paper is to review available studies investigating the effect of different processing methods on both the nutritional and sensory parameters of green beans. Understanding what temperature and packing methods preserve the most nutrients as well as color and texture can help manufacturers, consumers and home gardeners make a more informed decision about which green bean preservation method to use.

LITERATURE REVIEW

Green Beans Nutrient Content and Potential Health Benefits

Epidemiological studies of vegetables including green beans have shown protective effects against diseases such as: cancer, cardiovascular disease, cataract and macular degeneration.[5] The antioxidant properties of flavonoids and phenolic compounds found in green beans have been suggested to have protective effects against risk of several diseases by neutralizing free radicals.[5, 12] A lack of antioxidants in the body results in oxidative stress, which

decreases cell health by increasing oxidation of cells and decreasing the cell's ability to repair oxidative damage.[14] Flavonoids stored between the lipid and aqueous bilayers of the cell membrane function to prevent the generation of free radicals such as: hydroxyl, peroxyl, alkyl peroxyl, and superoxides.[13] Flavonoids act as antioxidants by donating an electron from the phenolic hydroxyl group or by using a phenolic ring to stabilize the unpaired electrons in free radicals.[13] In addition to flavonoids and phenolic compounds, green beans are a good source of ascorbic acid which is involved in electron transport reactions including collagen and carnitine synthesis where ascorbic acid acts as a reducing agent.[14] Green beans are also rich in folate which in a total oxyradical scavenging capacity assay showed twice the antioxidant activity of ascorbic acid.[13, 15, 16] Low folate consumption has been shown to increase to the risk of breast, ovarian, pancreas, brain, lung, cervix and colorectal cancer.[17]

In addition to antioxidant compounds, green beans are high in the essential polyunsaturated fatty acids: linoleic acid and α-linolenic acid which are important for formation of skin and hair as well as reproductive functions.[13, 18] As consumers increase their demand for green beans, there continues to be a growing market for frozen and canned green beans.

Consumer Demands

The demand for frozen green beans increased from a 4.9 to a 5.4 billion dollars market between 2008 and 2010.[7, 21] Consumers expect a product that is visually and texturally appealing as well as nutritional.[6] While consumers are also interested in the nutritional quality of green beans, they fail to take into consideration that nutrition labels do not account for degradation due to storage.[1] It is understood by consumers that processing is necessary in order to supply green beans throughout the year. Both canning and freezing are effective at preventing microbial

growth and spoilage from occurring during storage of one year while the shelf life of fresh green beans is limited to 8-10 days.[22] However, it is unknown whether canning or freezing retains nutritional and sensory parameters during storage that meet consumer expectations.

Processing Methods

Processing of green beans uses the same initial steps of washing, trimming, and blanching before specific steps for freezing or canning (Figure 1).[1] Home canning of green beans includes blanching at boiling point for one to two minutes.[11, 23] After blanching, green beans are packed into sterilized jars and boiling water is poured over the green beans. Salt (½ tsp/quart) is added to make a brine creating a more acidic environment. Both home and commercial canning require a headspace of one inch after the cans are filled with brine to allow for expansion during heating and to allow space for a vacuum seal to form.[11] Next, the jars are sealed and pressure cooked at 121°C for 20 minutes to ensure sterilization of the green beans.[11, 23] Compared to home canning, commercially canned green beans are thermally processed at 115°C for 15 minutes which is long enough to allow heat to penetrate the middle of the can ensuring the whole product is sterilized. Canned green beans are then naturally cooled down to room temperature (~21°C).

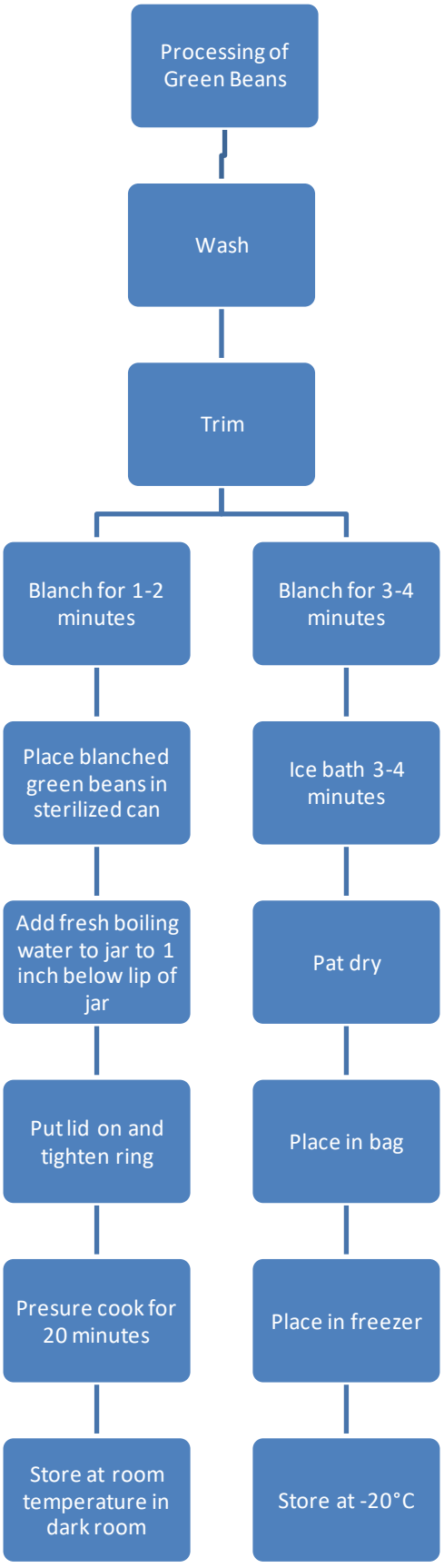

Figure 1: Canning and Freezing Home Processes

Freezing green beans includes washing trimming and blanching. In home freezing, blanching lasts for three to four minutes green beans are placed into an ice bath for three to four minutes then blotted dry and packaged in freezer bags for freezing.[26] In contrast, in commercial freezing, green beans are frozen by individual quick freeze (IQF) which uses CO_2 to quickly freeze 10,000 to 15,000 pounds of green beans per hour while on a conveyor belt.[26] IQF prevents the water in the cells from forming large ice crystals which causes less damage to the tissue reducing discoloration and softening of green beans.[26]

Effect of Processing Methods on Nutrient Content

The processing that green beans undergo uses heat to stabilize the green beans, though the heat also may affect nutrient content.

Frozen green beans are only blanched, not thermally processed. Canned green beans are both blanched and thermally processed which

would cause greater nutritional losses during processing compared to frozen green beans.

Ascorbic Acid

Tosun and Yücecan conducted a study to evaluate the effects of pre-processing on ascorbic acid content in commercially frozen green beans.[27] Since ascorbic acid is sensitive to heat and oxidation, it was used to monitor the amount of nutrient loss that occurs due to processing.[27]

Green beans were harvested and stored for 24 hours at the factory before trimming and then blanched for 2.5 minutes at 94-96°C.[27] Samples (n=10 g) were assessed in triplicate for ascorbic acid content after blanching.[27] Results showed 26.9% loss ($P < 0.05$) of ascorbic acid in blanched green beans compared to fresh green beans.[27] The authors suggested significant loss may be due to ascorbic acid leaching into the blanching water. [27] Trimming ends and blanching disrupts the cell structure which makes ascorbic acid more prone to leaching into the water.

Jiratanan and Liu determined the effects of different thermal processing temperatures and times on ascorbic acid content in unblanched canned green beans.[10] Green bean treatment groups consisted of eight cans of green beans.[10] The control group consisted of canned green beans that were not blanched or thermally processed.[10] Treatment groups consisted of green beans canned in water without blanching, then thermally processed at 115°C at different times of 10, 20 and 40 minutes.[10] The other treatment group consisted of green beans canned in water without blanching then thermally processed for 20 minutes at different temperatures of 100, 115 and 121°C.[10]

Results showed that thermally processed canned green beans for 20 minutes at different temperatures of 100, 115 and 121°C had no significant effect on ascorbic acid content compared to the fresh green beans.[10] Thermally processing canned green beans at a constant temperature

of 115°C for 10 minutes decreased ($P < 0.05$) ascorbic acid by 0.65 mg/100 g (12.1%).[10] The effect of thermal treatment on ascorbic acid content after 20 and 40 minutes was insignificant compared to the control group.[10] The authors suggested that greater loss of ascorbic acid after 10 minutes of thermal processing compared to 20 and 40 minutes may be due to the water the green beans were canned in creating a reducing environment in which dehydroascorbic acid (DHAA) was reduced to ascorbic acid causing the elevated level of ascorbic acid identified post thermal processing.[10] Further oxidation of DHAA resulted in less nutritional green beans.[10] DHAA is the oxidized form of ascorbic acid. Other studies have shown similar results between the length of thermal treatment and the amount of ascorbic acid lost.[10] As the length of the thermal treatment was reduced, the amount of ascorbic acid lost was also reduced.[10]

Phenolic Compounds

In addition to ascorbic acid and DHAA, phenolic compounds are also affected. Jirantanan and Liu also measured the effects of processing time and temperature on phenolic compounds in green beans. Results showed that thermal processing of green beans at 115°C for 10, 20 and 40 minutes decreased ($P < 0.05$) total phenolics compared to fresh green beans by 36, 32 and 30%, respectively.[10] Total phenolics also decreased ($P < 0.05$) compared to the control when processed for 20 minutes at 100, 115 and 121°C by 40, 32 and 23%, respectively.[10] The decrease of phenolic compounds after thermally processing at 115 and 121 °C in phenolic compounds may be due to the matrix softening effect which allows easier extraction of phenolic compounds after severe processing.[10] This decrease after higher temperature treatments may also be due to the matrix softening effect. Flavonoids are another antioxidant that are affected by thermal processing.

Flavonoids

Jirantanan and Liu also measured the effect of different thermal processing times and temperatures on flavonoid content in green beans. Results showed that thermally processing canned green beans at 115°C for 10, 20 and 40 minutes compared to fresh green beans decreased ($P < 0.05$) flavonoid content by 63, 58 and 62%, respectively.[10] These decreases in flavonoid content may be due to leaching of flavonoids into the water.[10] Thermally processing canned green beans at 100, 115, and 121°C for 20 minutes also showed decreased ($P < 0.05$) flavonoids compared to fresh green beans by 65, 58 and 55%, respectively.[10] The higher processing temperature may have allowed for additional breakdown of tissues allowing more flavonoids to leach out causing a decrease of flavonoids in the green beans regardless of processing time.[10] Another nutrient that has antioxidant properties by scavenging free radicals is folate, which is also prone to leaching during processing.

Folate

A study by Delchier et. al., determined folate content of canned and steamed or blanched fresh and frozen green beans. Three batches were prepared for each treatment group and samples were analyzed in duplicates.[15] Fresh green beans were divided into two groups. Group 1 was fresh green beans that were immediately frozen at -80°C until analysis.[15] Group 2 was separated into two sub-groups.[15] Group 2a consisted of fresh green beans blanched at 100°C for 8 minutes. Green beans and water used for blanching were stored at -80°C until analysis.[15] Group 2b was fresh green beans steamed for 20 minutes then stored at -80°C until analysis.[15] The commercially frozen green beans were boiled for 13 minutes. Green beans and the water used for boiling were stored at -80°C until analysis.[15] Canned green beans and brine were stored at -80°C until analysis.[15]

Loss of folate due to leaching was determined by the amount of folate measured in the water or brine.[15] Folate content of commercially canned green beans equilibrated between the green beans and the brine.[15] Folate content in frozen-boiled green beans decreased by 20% due to leaching into the water.[15] The heating of the green beans after freezing may have decreased cell structure allowing folate to leach from cells as well as the trimmed ends.[15] Results showed that folate, which is sensitive to heat and oxidation was not significantly affected after steaming or blanching green beans compared to fresh green beans.[15] Steaming green beans may have preserved folate content as there was no direct contact with the water preventing any leaching from occurring.[15] Blanched green beans may have retained folate content due to the short period of blanching time which Frozen boiled and canned green beans both had folate leach into the water and brine until it equilibrated. The nutritional value of green beans is not only in antioxidants, phytochemicals and vitamins, but in fatty acids as well. Green beans have linoleic and α-linolenic acid which are both affected by processing.

Fatty Acids

Gonzalez-Casatro et.al., determined the fatty acid content of fresh green beans and green beans that were blanched at 100°C for four minutes. Measurements were assessed on duplicates of fresh and blanched green beans. Linoleic and α-linolenic content of blanched green beans decreased ($P < 0.05$) compared to fresh green beans by 36 and 63%, respectively.[19] Linoleic and α-linolenic acids may decrease due to oxidation as both are essential polyunsaturated fatty acids. Linoleic has one less double bond which may have prevented it from oxidizing as quickly as α-linolenic acid.[19]

Overall the studies showed that blanching green beans for 2.5-4 minutes at 96-100°C will retain nutrients such as ascorbic acid, linoleic and α-linolenic acid by ~75, 64 and 37%,

respectively. Steam blanching green beans at 100°C for 20 minutes resulted in no significant change in folate content. Thermally processing canned green beans at 115°C for 20 minutes retained ascorbic acid, phenolics and flavonoids by 100%, 68% 42%, respectively.

Effect of Processing Methods on Sensory Parameters

Texture

Blanching of green beans causes varying degrees of texture loss depending on the temperature and duration of blanching. Canet et.al., determined the effects of blanching at different temperatures and times on green bean texture. Fresh green beans (70 kg) were blanched at 65, 70, 75, 80, 85, 90, and 97°C for 0, 2.5, 5, 10, 20 and 40 minutes.[8] Texture was determined by Kramer maximum force test which measured green bean firmness.[8] Results showed no significant effect on green bean firmness until the temperature of water reached 85°C or above after 2.5-40 minutes.[8] Changes in green bean firmness were insignificant after thermally processing for 2.5-10 minutes at 85°C.[8] Green bean firmness decreased approximately 50% after blanching at 85°C for 40 minutes compared to fresh green beans.[8] Blanching green beans for 40 minutes at 90 and 97°C compared to fresh green beans resulted in loss of 81% and 90% firmness, respectively.[8] Green bean firmness was significantly higher when blanched at 75°C for five minutes compared to blanching at 97°C for five minutes.[8] Generally, blanching at 65-80°C retained firmness better than blanching at higher temperatures of 85-97°C, though sterilization may not have occurred between 65 and 80°C. Additionally, the amount of time green beans are blanched at 65-80°C did not cause significant differences in texture compared to fresh green beans. Green beans processed between 65 and 80°C may have retained firmness better than green beans blanched at 85-97°C due to the breakdown of cell walls. Blanching at 85-97°C may cause cell walls to become weaker at the higher temperature causing a softer green

bean. Canet et. al., determined the ideal temperature range for retaining firmness of green beans was 65-80°C.

Krebbers et. al., investigated the texture of home canned and frozen green beans. Canned green beans consisted of duplicate samples (360 g) blanched at 90°C for four minutes then placed in glass jars and thermally processed for sterilization at 118°C for 30 minutes.[9] Frozen green beans (360 g) were steam blanched for 10 minutes then frozen at -20°C.[9] After freezing for one month, frozen green beans were defrosted in the microwave for four minutes.[9] Firmness was analyzed using a texture analyzer Warner-Bratzler test.[9] Results showed 80% decrease of firmness in the frozen green beans and 97% of firmness was lost in home canned green beans after 31 days of storage.[9] Overall, canning retained less firmness compared to fresh green beans.

Color

Color is another sensory parameter which changes during the heating, yet sensory says the color changes are not undesired. Color changes may be due to chlorophyll pigment degradation which leads to an undesired olive-green color.[8, 9] Krebbers et al, analyzed the color of fresh, home canned and home frozen green beans. Color was analyzed using a Minolta Chroma meter. Color measurement of L^*, a and b values were obtained by performing 15 measurements of color within 10 minutes of samples being opened from a jar or a bag.[9] a-value represents the red to green color axis, where a negative value is green, and a positive value is red.

Results showed that canning green beans resulted in a dark olive-green color (a = -1.2) compared to the bright green of fresh green beans (a = -16.1).[9] Frozen green beans changed ($P < 0.05$) to a light olive-green (a = -17.9) color compared to fresh green beans.[9] The luminescence of home frozen (L^* = 32.0) and canned green beans (L^* = 30.0) were darker ($P < 0.05$) than fresh green beans (L^* = 41.5) but canned green beans were the darkest, overall.[9] b-value was

also measured where yellow is a positive value and blue is a negative value. Frozen (b = 18.0) and canned (b = 17.2) green beans expressed greater ($P < 0.05$) yellow pigments (b-values) than fresh green beans (b = 22.1). There was no significant difference between home canned and frozen green beans b-value.[9] The authors suggested that differences in color of the home canned green beans may be due to plant cells becoming softer, allowing chlorophyll degrade.[9]

Overall based on the studies evaluating color and texture blanched-frozen green beans retained more firmness than canned green beans. Canned green beans underwent more heat processing and as a result green beans were softer than fresh green beans. Thermally processing canned green beans at a lower temperature between 65 and 80°C maintained green bean firmness and color. Future studies could measure firmness and cell wall structure to determine if this is an accurate hypothesis.

Historically, the suggested length of time that the green beans are stored has been based on a sensory panel measuring color and texture rather than nutritional attributes.[28] Yet, nutrient losses from storage vary depending on the processing and storage methods.[11]

Storage Period

Ascorbic Acid

Bouzari et. al., evaluated the effects of frozen storage on ascorbic acid content of green beans. Green beans were trimmed and steam blanched for 3.5 minutes at 93.3°C then placed in a freezer at -32°C.[25] After an hour in the freezer, green beans were separated into three samples (300 g) and stored for 0, 10, or 90 days at -27.5°C.[25] The paper did not provide justification for the temperature change from -32°C to -27.5°C. Freezing green beans at the lower temperature may have been to freeze the green beans faster in order to decrease the size of ice crystals formed

which prevents cell damage. Fresh green beans were stored in 300 g samples in breathable polyethylene pouches for 0, 3 and 10 days at 2°C.[25] There were six replicate samples for each group.[25]

Results showed that ascorbic acid in fresh green beans decreased ($P < 0.05$) by 37% after storage for 10 days, while ascorbic acid content of frozen green beans remained stable indicated by no significant loss of ascorbic acid after 90 days of storage at -20°C.[25] The author suggested that the frozen green beans ascorbic acid loss may be due to slowing enzymatic activity in the frozen green beans.[25]

Tosun and Yücecan evaluated how storage duration affects ascorbic acid content in commercially frozen green beans.[27] Commercially frozen green beans and fresh green beans were obtained from the same manufacturer.[27] Commercially frozen green beans (n=3 samples of 10-75 g) were transferred after 3 and 6 months storage at -18°C from the manufacturer's freezer for analysis.[27]

Results showed that freezing did not prevent the loss of ascorbic acid. After three months of frozen storage ascorbic acid decreased ($P < 0.05$) by 4.77 mg/100 g (41.5%) compared to fresh green beans.[27] Freezing green beans for six months caused ascorbic acid to decrease ($P < 0.05$) by 5.71 mg/100 g (49.6%) compared to fresh greens.[27] The authors suggested decreases in ascorbic acid content was due to enzymatic activity.[27] Freezing the green beans slowed the enzymatic activity, but did not stop the enzymatic activity completely.[27] Another study determined whether home freezing had an effect on ascorbic acid content in green beans.

Howard et. al., determined the influence of frozen and refrigerated storage on ascorbic acid content of green beans.[29] Three field replications of green beans (454 g) were harvested and stored for 8-12 hours in a refrigerator at 4°C before any blanching.[29] Preparation of the frozen

green bean samples included washing, trimming, cutting into 3 inch pieces and steam blanching at 90°C for 60 seconds.[29] Green beans were cooled in an ice bath for 1.5 minutes before excess water was drained. Samples (454 g) were packaged in heat sealed freezer bags and frozen at -40°C for two days before being moved to a chest freezer at -20°C for one year. [29] Frozen green beans were analyzed after 4, 7, 16, 21, 112, 224, and 365 days. Samples of (454 g) fresh green beans were refrigerated at 4°C and stored for 1, 4, 8, and 16 days in Ziploc vegetable bags.[29] All samples were measured in triplicate.[29]

Results showed that after four days of frozen storage, the ascorbic acid content of the green beans increased ($P < 0.05$) from 15.2 ± 0.6 mg/100 g to 24.7 ± 2.8 mg/100 g. After seven days of storage, ascorbic acid decreased insignificantly to 11.4 ± 0.2 mg/100 g.[29] Ascorbic acid content of frozen green beans continued to decrease ($P < 0.01$) to 6.9 ± 0.6 mg/100 g after 365 days of storage.[29] The authors suggested the initial increase in ascorbic acid content after four days frozen storage was due to variation of the samples.[29] Ascorbic acid in fresh-refrigerated green beans decreased ($P < 0.01$) from 15.2 ± 0.6 mg/100 g to 1.3 ± 0.4 mg/100 g after 16 days of storage.[29] The authors suggest that the decrease during refrigeration was due to oxidation.[29] Oxidation was likely to occur because enzymes were still active since the green beans were not steam blanched to slow enzymatic oxidation from occurring.[29] The authors stated that the decreased rate of ascorbic acid loss in frozen green beans compared to the fresh-refrigerated green beans was due to the slowing of enzymes that cause ascorbic acid oxidation.[29] Another antioxidant in green beans that is affected by storage is β-carotene.

β-carotene

Howard et. al., also measured the content of β-carotene after one year of frozen storage. Results showed that β-carotene of frozen green beans decreased ($P < 0.05$) 15% from 173 ± 19 to

148 ± 14 IU/100 g after one year of storage.[29] β-carotene of refrigerated green beans decreased ($P < 0.05$) 11% from 183 ± 21 IU/100 g to 164 ± 17 IU/100 g after 16 days storage.[29] The loss of β-carotene after one year of frozen storage was about similar to refrigeration of fresh green beans after 16 days.[29] This may be due to the steam blanching that the frozen green beans underwent.[29] The authors believed that steam blanching allowed easier extraction of β-carotene compared to the fresh-refrigerated green beans.[29] Storage effect on antioxidants such as β-carotene and ascorbic acid may also affect fatty acid composition since fatty acids are susceptible to lipid oxidation.

Fatty Acids

Gonzalez-Casatro et.al., determined the fatty acid content of green beans at regular intervals over a year of storage at -22°C. Green beans were either fresh or blanched at 100°C for four minutes then frozen at -22°C.[19] Both fresh and blanched green beans were hand or vacuum packed in order to remove excess air to minimize oxidation.[19] There was no significant difference in the content of linoleic and α-linolenic acid between hand packed and vacuum packed blanched green beans.[19] The insignificant difference between hand and vacuum packed green beans shows that the amount of air that is removed from the bags during hand packing is enough to minimize oxidation of linoleic and α-linolenic acid.[19] Fatty acid content was measured at 1, 2, 3, 5, 7, 9 and 12 months of freezing.[19] Each treatment group consisted of 10 samples.[19]

Results showed that fatty acid content in fresh-frozen green beans was lower (25-40 mg/100 g) than in blanched-frozen green beans within the first month.[19] After 12 months storage fresh-frozen and blanch-frozen green beans had no significant loss of linoleic or α-linolenic acid compared to initial measurements of the fresh green beans. The fresh-frozen green beans may have had more oxidation in the first month, but oxidation slowed after that, allowing

insignificant losses of linoleic and α-linolenic acid.[19] Nutrients are not the only aspect of green beans that are affected by storage; sensory changes such as color and texture also change due to storage.

Color

A study conducted in the Netherlands by Krebbers et.al., determined color changes in home canned and home frozen green beans during storage. Green beans were purchased at a local store and stored at 6°C for two days before ends were trimmed. Green beans were blanched at 90°C for four minutes before being placed in glass jars with a brine.[9] Jars were sealed and thermally processed at 118°C for 30 minutes.[9] Frozen green beans were blanched at an unknown temperature for 10 minutes then frozen at -20°C.[9] Frozen green beans were defrosted in the microwave for four minutes before analysis which had no significant affect on the color of the green beans.[9] Fresh green beans were used as a control and stored at 6°C for one month. All samples were measured in triplicates.[9]

Results showed that one month of storage caused a significant difference in *a*-value measuring green (-*a*) to red (+*a*) compared to fresh green beans. Frozen green beans (*a* = - 17.9) *a*-value was significantly higher than fresh green beans (*a*= -16.1). *a*-value of canned green beans (*a* = -1.2) was significantly lower than fresh green beans. The *a*-value of frozen green beans was the brightest hue of green while canned green beans were a dark, olive green color compared to fresh green beans. *b*-value was also measured after one month of storage. *b*-value indicates blue (-*b*) to yellow (+*b*). Canned (*b* = 17.2) and frozen (*b* = 18.0) green beans were significantly ($P < 0.05$) different from fresh green beans (*b*= 22.1).[9] *L**- value represents the luminescence of both *a* and *b* color axes. The luminescence of frozen (*L**= 32.0) and canned (*L** = 30.0) green beans were significantly ($P < 0.05$) different from fresh green beans (*L**= 41.5).[9]

These changes in color were suggested by the author to be due to the pre-processing heat treatments that frozen and canned green beans underwent.[9] After one month of refrigeration green beans were spotted due to microbial spoilage.[9]

Texture

Krebbers et.al., also measured firmness of green beans after frozen and canned storage using Texture Analyzer TA-XT2i (Stable Micro Systems, Godalming, UK) with a Warner-Bratzler Blade. Blanching, one month of frozen storage and defrosting significantly ($P < 0.05$) decreased green bean firmness by 90% compared to fresh green beans.[9] Canned green beans were also softer ($P < 0.05$) than fresh green beans by 97%.[9] Frozen green beans may have retained texture better than canned green beans because they only underwent blanching not thermal processing as did canned green beans. Based on texture, frozen green beans retained firmness better than canned green beans.

Overall evaluation of all studies showed that blanching green beans for 2.5 minutes at 94-96°C resulted in a 26.9% decrease in ascorbic acid. Ascorbic acid content decreased 25% after 7 days compared to fresh green beans. Storing frozen green beans for 3 and 6 months decreased ascorbic acid content by 41 and 49%, respectively. Thermally processing canned green beans at 100°C for 20 minutes of ascorbic acid content was insignificant. Color and texture was also affected by blanching, thermal processing and storage of green beans. Blanching green beans resulted in a darker green color as well as a softer green bean. Additionally, thermally processed canned green beans caused the green beans to become softer than fresh green beans. Freezing green beans caused the color to change to a dark green and caused the green beans to become softer compared to fresh green beans.

Summary and Conclusions

The recommended processing methods of green beans are similar for both canning and freezing. The difference is that home canned green beans are blanched for one to two minutes and thermally processed after green beans are placed in the can while home frozen green beans are blanched for three to four minutes at 100°C. Studies reported that steam blanching at 90°C for 3.5 minutes did not affect ascorbic acid content after 90 days of frozen storage at -20°C, while the ascorbic acid content of commercially frozen green beans at -18°C for 3 and 6 months lost 41.5 and 49.6%, respectively.[25, 27] Thermally processing canned green beans at 100°C for 20 minutes caused no significant effect on ascorbic acid content and 60% loss of phenolics and 35% loss of flavonoids. Storage of canned green beans was not presented due to lack of current research.

Processing and storage not only affect the nutrient content of green beans, but also color and texture. Blanching green beans between 65 and 80°C for 2.5-10 minutes had no significant effect on color or texture while blanching between 85 and 97°C for 20-40 minutes significantly decreased color and softened green beans by 50-90%. Green beans frozen at -20°C had a brighter green color compared to fresh green beans. Storage of frozen green beans retained 10% of firmness compared to fresh green beans. For canned green beans, after thermal processing green beans became an olive-green color and retained 3% of firmness compared to fresh green beans. After one month storage, canned green beans had a dark olive-green color.

Overall, steam blanching green beans at 90°C for 3.5 minutes before freezing at -20°C retains nutrients, color and texture better for consumers who plan on consuming green beans within three months storage. Canned green beans maintain color and texture over an extended period of time. Consumers who prefer to store green beans for greater than three months may benefit more from canned green beans. Based on the review of the literature it is recommended

that home frozen green beans be chosen for storage of three months or less and canned green beans be chosen for storage greater than three months. For commercially processed green beans less ascorbic acid is retained than home frozen green beans after three months of storage. Commercially processed green beans are blanched for less time than home frozen green beans, allowing oxidation of ascorbic acid to occur.

Limitations of the studies that were reviewed includes: using short periods of storage, no recent canned green bean studies, analyzing nutrients that are not high in green beans, measuring color and firmness without analyzing nutrient content, not including analyzing enzymatic activity throughout the canning and freezing processes, using a small number of replicates, and using fresh green bean as the control. Studies that measured color and texture suggested changes were due to pectin, chlorophyll and cell wall structure without measuring these three parameters, studies also did not include consumer preferences of texture and color of green beans.

Future Studies

Future research should investigate different home processing methods including by analyzing at what temperature and time enzymatic reactions are stopped during blanching to retain greater ascorbic acid, color and texture. Blanching at 70-80°C for 2.5 minutes retained color and texture, but ascorbic acid and enzymatic activity were not measured. Steam blanching at 100°C for 2-4 minutes is another pre-processing method that could use additional research to determine the effect on nutritional and sensory parameters. Additionally, future studies may consider examining the nutrient content, texture and color after two years of storage for canned and frozen green beans as canned green beans are shelf-stable for more than a year and there are no recent studies of canned green bean storage. However, the longest period that any reviewed studies analyzed was frozen green beans after one year. Analyzing nutrients that are high in

green beans (ascorbic acid, vitamin A, folate, β-carotene, riboflavin, linoleic acid, α-linolenic acid, and flavonoids) with increased replicates of 6 or more at pre-processing, processing and storage to better understand what nutrients are lost under what conditions to help consumers make a more educated choice of processing methods.

Preliminary Study

Hypothesis: Blanching green beans at boiling point for three to four minutes will result in a softer texture, olive-green colored green bean compared to fresh green beans.

Objective: To determine the effect of blanching green beans on texture and color compared to fresh green beans.

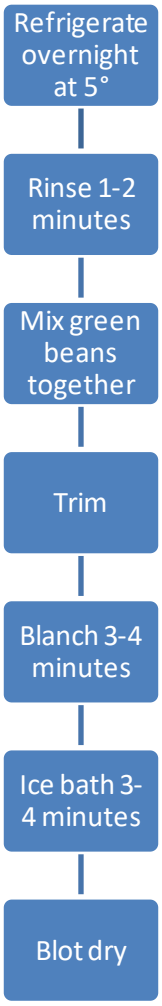

Figure 2: Blanching

Experimental Design

Green beans were grown at the West Virginia University Organic Farm in summer 2015. Green beans were harvested twice and stored overnight in a refrigerator at 5°C after both harvests. Green beans were rinsed under cold water for one to two minutes and mixed to ensure a homogenous mixture from the different plots. Green beans were trimmed to remove the stems on both ends and left whole. Treatments consisted of 4 samples of fresh and 4 samples of blanched green beans. Green bean samples (~250 g) were blanched at boiling point for three to four minutes. Blanched green beans were removed from boiling water and placed directly into an ice bath for three to four minutes before removing and blotting dry (Figure 2). Fresh and blanched green beans were analyzed for texture and color on the same day as blanching. These processing steps were repeated for each harvest. Green beans were also canned

and frozen, but data were not collected in the preliminary study.

Statistics

Data was expressed as mean ± standard deviation of six replicates. Two-tailed t-test was used to determine the differences in texture and color of blanched compared to fresh green beans. Significant differences were indicated by ($P < 0.05$). Microsoft Office Excel 2007 was used for all statistical analysis.

Methods

Texture Analysis

A texture analyzer (TA-DHi, Texture Tech. Corp, Hamilton, MA) was used to perform texture analysis. The Warner-Bratzler Shear Device measures the shear force of resistance of a sample compared to initial tenderness of the green beans.[30] Warner-Bratzler Shear has one blade that is comparable to the action of the front incisor teeth slicing through a food. Warner-Bratzler Shear was performed 6 times by placing one green bean in the cell with the blade going between the beans in the pod.

The Kramer maximum force shear cell measure the total amount of force necessary to break the surface of the samples and measures firmness of peak force divided by the weight (g) of the sample. Kramer maximum consist of multiple blades NS force has wider blades Warner-Bratzler Shear Device which causes a shear/compression which is comparable to mouth feel while biting or chewing a food.[30] Kramer maximum force was performed 6 times for fresh and blanched green beans by placing four green beans down directly next to each other for testing.

Color Analysis

Color was assessed for fresh green beans within 24 hours of harvesting and blanched green beans were assessed within 4 hours of blanching. All green beans had both ends trimmed and color was measured at room temperature (~ 25°C). Color was measured using a colorimeter Minolta Camera Co Ltd, Osaka, Japan). Green bean color was measured on the outside along a flat even part of the pod by applying pressure to create an even surface. Four data points were collected from various points of the green beans. *L** measures the luminescence of the sample, where a higher value is lighter, and a value closer to 0 is darker. The *a*-value measures green to red, where green is a –*a*-value and red is a +*a*-value. The *b*-value measures a blue to yellow ratio where blue is a –*b*-value and yellow is a +*b*-value. (Figure 3)

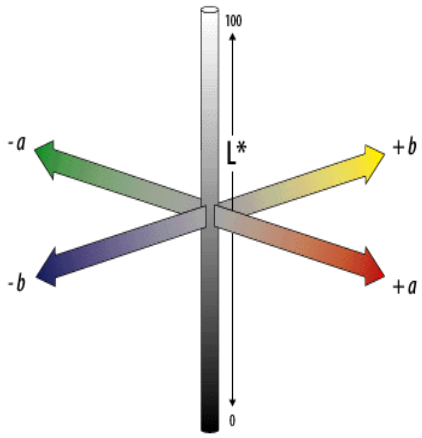

Figure 3: *L** = luminescence *a* = green-red and *b* = yellow-blue scale of the color analysis

Results/Discussion

Texture

Table 1 shows the results of the Warner-Bratzler measuring maximum force and Kramer Maximum Force also measuring maximum force. Blanched green beans were softer ($P < 0.05$)

than fresh green beans by Warner-Bratzler shear force indicating that the cell wall structure of blanched green beans was less stable after thermal treatment which results in a softer green bean. The softening of blanched green beans may be due to pectin breaking down during thermal exposure in blanching.[8] In a study by Canet et. al., it was determined that blanching green beans at higher temperatures at 90 and 97°C for 10-40 minutes caused greater losses in firmness as pectin was broken down.[8] Blanching green beans for 40 minutes at 85°C retained 50% of original firmness.[8] While blanching at 70°C for 40 minutes retained the greatest firmness of green beans.[8] Green beans blanched at a higher temperature meet consumer preferences of softer boiled green beans over crisper steamed green beans.[31]

Table 1: Maximum Force/Firmness of fresh and blanched green beans

Treatment	**Warner-Bratzler (g)**	**Kramer Maximum Force (g/g weight)**
Fresh	18737 ± 5918^{b}	9116 ± 14406^{a}
Blanched	7246 ± 276^{a}	1403 ± 238^{a}

Data are means ± standard deviation, n = 6 a two-tailed t-test was performed. Different letters in rows indicate differences of $P < 0.05$.

Kramer Maximum Force did not result in significant ($P > 0.05$) differences between fresh and blanched green beans. This may be due to the placement of green beans in the cell where Kramer was more likely to pass through beans since there were multiple green beans and multiple blades compared to Warner-Bratzler which has one blade. Placing the green bean so the blade passed through the pod allowed for consistency that was not possible with Kramer Maximum Force with multiple blades and multiple green beans. Kramer maximum force had a large standard deviation which prevents it from being statistically reliable data. Blanching of green beans affected the color as well as the texture compared to fresh green beans.

Color

Table 2 shows the results of color analysis. Blanched green beans had a lower ($P < 0.0003$) L^*-value resulting in an olive-green color compared to the fresh green beans which had a vibrant color. Blanched green beans also had a lower ($P < 0.05$) a-value compared to fresh green beans. Blanched green beans became a darker green compared to fresh green beans which retained a bright green color. The b-value blanched green beans was lower ($P < 0.05$) than fresh green beans indicating that the color of blanched green beans was a less vibrant yellow than fresh green beans. Canet et. al., had similar findings after blanching green beans at 90 and 97°C for 10-40 minutes which resulted in an olive-green color compared to fresh green beans which had a bright green color.[8] Canet et. al., suggested that chlorophyll pigments degraded during heating which caused a change in the green color of green beans.[8] Canet et. al., also determined that a short blanching for 2.5 to 5 minutes at 65°C caused an initial increase in chlorophyll creating a brighter green compared to fresh green beans.

Table 2: Color Analysis of fresh and blanched green beans

Treatment	***L****	***a***	***b***
Fresh	52.96 ± 2.76^{a}	-16.95 ± 0.88^{a}	29.40 ± 1.56^{a}
Blanched	44.55 ± 2.74^{b}	-21.15 ± 1.37^{b}	26.35 ± 3.14^{b}

Data are means ± standard deviation, n= 4 a two-tailed t-test was performed. Different letters in rows indicate differences of $P < 0.05$

Based on our preliminary study, green beans blanched at boiling point for three minutes resulted in loss of firmness and color vibrancy and greenness resulting in an olive-green color. Panelists preferred softer green beans over a firm, crisp green bean.[31] The color of the green beans was not reflective of consumer preferences.[31] Panelists who selected bright green for their

preferred color of green beans chose olive-green colored green beans as frequently as panelists who selected olive-green colored green beans as their preference.[31] Therefore, blanching of green beans is recommended at a 100°C for three to four minutes to meet consumer preferences of a soft green bean which will result in an olive-green color.

References

1. Rickman J.C., Barrett D.M., Bruhn C.M. Nutritional comparison of fresh, frozen and canned fruits and vegetables. part 1. vitamins C and B and phenolic compounds. *Journal of Science and Food Agriculture*. 2007;87(6):930-944.

2. Guo L, Ma Y, Sun D, Wang P. Effects of controlled freezing-point storage at 0 °C on quality of green bean as compared with cold and room-temperature storages. *Journal of Food Engineering*. 2008;86(1):25-29.

3. Department of Agriculture US. Vegetables 2015 summary. 2016.

4. de La Cruz Garcia C, Lopez Hernandez J, Simal Lozano J. Gas chromatographic determination of the fatty-acid content of heat-treated green beans. *Journal of Chromatography A*. 2000;891(2):367-370.

5. Turkmen N, Sari F, Velioglu Y.S. The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food Chemistry*. 2005;93(4):713-718.

6. Iborra-Bernad C, Philippon D, García-Segovia P, Martínez-Monzó J. Optimizing the texture and color of sous-vide and cook-vide green bean pods. *LWT - Food Science and Technology*. 2013;51(2):507-513.

7. Martins RC, Silva CLM. Kinetics of frozen stored green bean (phaseolus vulgaris L.) quality changes: Texture, vitamin C, reducing sugars, and starch. *Journal of Food Science*. 2003;68(7):2232-2237.

8. Canet W, Alvarez M.D, Luna P, Fernández C, Tortosa M.E. Blanching effects on chemistry, quality and structure of green beans (cv. moncayo). *European Food Research and Technology*. 2005;220(3):421-430.

9. Krebbers B, Matser A.M, Koets M, Van den Berg R.W. Quality and storage-stability of high-pressure preserved green beans. *Journal of Food Engineering*. 2002;54(1):27-33.

10. Jiratanan T, Liu R.H. Antioxidant activity of processed table beets (beta vulgaris var, conditiva) and green beans (phaseolus vulgaris L.). *Journal of Agriculture and Food Chemistry*. 2004;52(9):2659-2670.

11. Andress H, Harisson. Complete guide to home canning: Guide 1 principles of home canning. http://nchfp.uga.edu/publications/usda/GUIDE01_HomeCan_rev0715.pdf. Accessed November/10, 2015.

12. Ewald C, Fjelkner-Modig S, Johansson K, Sjöholm I, Åkesson B. Effect of processing on major flavonoids in processed onions, green beans, and peas. *Food Chemistry*. 1999;64(2):231-235.

13. Gropper S, Smith J, Groff J. *Advanced nutrition and human metabolism*. 4th ed. CA, USA: Peter Marshall; 2005:600.

14. Mahan L.K, Escott-Stump S, Raymond J.L. *Krause's food and the nutrition care process*. 13th ed. Missouri: Elsevier; 2012. 8/10/2016.

15. Delchier N, Reich M, Renard C.M. Impact of cooking methods on folates, ascorbic acid and lutein in green beans (phaseolus vulgaris) and spinach (spinacea oleracea). *LWT-Food Science and Technology*. 2012;49(2):197-201.

16. Pitkin R.M,. Folate and neural tube defects. *American Journal of Clinical Nutrition*. 2007;85(1).

17. Duthie S.J., Folate and cancer: How DNA damage, repair and methylation impact on colon carcinogenesis. *Journal of Inherited Metabolic Disease*. 2011;34(1):101-9.

18. United States Department of Agriculture. Full report (all nutrients) 11052, beans, snap, green, raw. 2016.

19. Gonzalez-Castro M, Oruña-Concha M, Lopez-Hernandez J, Simal-Lozano J, Ganza-Gonzalez A. Effects of blanching, freezing and freeze-drying on the fatty acid contents of green beans. *Zeitschrift für Lebensmittel-Untersuchung und Forschung*. 1996;203(4):370-373.

20. Ricciotti E, FitzGerald GA. Prostaglandins and inflammation. *Arteriosclerosis Thrombosis and Vascular Biology*. 2011;31(5):986-1000.

21. Buzby J.C., Wells H.F., Kumcu A., Lin B.H., Lucier G., Perez A. Canned fruit and vegetable consumption in the united states an updated report to congress. 2010.

22. Barrett D.M., Maximizing the nutritional value of fruits and vegetables. *Food Technology*. 2007;61:40-44.

23. United States Department of Agriculture. Shelf-stable food safety. 2015.

24. Rickman J.C., Bruhn C.M., Barrett D.M., Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. vitamin A and carotenoids, vitamin E, minerals and fiber. *Journal of Science and Food Agriculture*. 2007; 87(7):1185-1196.

25. Bouzari A, Holstege D, Barrett D.M. Vitamin retention in eight fruits and vegetables: A comparison of refrigerated and frozen storage. *Journal of Agriculture Food Chemistry*. 2015;63(3):957-962.

26. Garden-Robinson J. *Food freezing guide*. NDSU Extension Service; 2004.

27. Tosun, B.N.,Yücecan, Sevinç. Influence of commercial freezing and storage on vitamin C content of some vegetables. *International Journal of Food Science and Technology*.

2008;43(2):316-321.

28. Martins R, Silva C. Frozen green beans (phaseolus vulgaris, L.) quality profile evaluation during home storage. *Journal of Food Engineering*. 2004;64(4):481-488.

29. Howard, L.A., Wong, A.D., Perry, A.K.,Klein, B.P. β-Carotene and Ascorbic Acid Retention in Fresh and Processed Vegetables. *Journal of Food Science*. 1999, 64:929-936.

30. Xiong, R., Cavitt, L.C., Meullenet, J.F., Owens, C.M. Comparison of allo-kramer, warner-bratzler and razor blade shears for predicting sensory tenderness of broiler breast meat. 2016;27(2) 179-199.

31. Baron, R.F., Penfield, M.P. Panelist texture preferences affect sensory evaluation of green bean cultivars (phaseolus vulgaris l.). 1991;58(1) 138-139.