EFFECT OF FILL WEIGHT ON THE F-VALUE DELIVERED TO TWO STYLES OF GREEN BEANS PROCESSED IN A STERILMATIC RETORT

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ABSTRACT

The effect of fill weight on the F-value delivered to two different styles of green beans heated in a FMC Sterilmatic processing continuous cooker/cooler was evaluated biologically as a function of container fill weight. Four different fill weights of each product, French-style and 1-inch cut green beans, were evaluated. All tests were carried out at least two times. F-values were measured using biological indicator units (BIU) filled with a suspension of *Bacillus stearothermophilus* spores and calibrated at 121.0°C. The F(250°F)-value decreased 2–3 min when the fill weight in 300 × 406 cans was increased from 11.5 to 13.0 oz.

INTRODUCTION

THIS IS THE REPORT of a series of experiments carried out to evaluate the effect of fill weight on the F-value delivered to two different styles of green beans: regular 1-inch cut and French cut. The study was carried out in a commercial plant; the cans were heated in an FMC Sterilmatic food sterilization machine. Biological indicator units (BIU) were used to measure the F(BIO)-value delivered to the cans of green beans in the sterilization process because of the difficulty in directly measuring temperatures in cans using thermocouples when the cans are heated in the FMC Sterilmatic continuous cooker/cooler.

The count reduction method (Yawger, 1967) was used in this project; the bacterial spores were in a buffer solution in plastic rods (Pflug, 1976) rather than inoculated directly into the product. The use of BIUs for measuring the F-value delivered to cans of food heated in an agitating mode have been reported previously by Pflug et al. (1980).

The objective of these experiments was to determine under plant conditions the effect of fill weight on the F-value delivered to cans of green beans heated in an FMC Sterilmatic continuous cooker/cooler.

MATERIALS & METHODS

Experimental plan

Five experiments were carried out during the 3-day period, July 25, 26, and 27, 1978, at the Green Giant Company plant in Beaver Dam, Wis. Tests were carried out using both regular 1-inch cut green beans and French-style green beans (mature green beans sliced longitudinally in about 1/8-inch slivers).

French-style green beans were used in Experiments I and II. In Experiment I the fill weights were: 11.5, 12.0, 12.5, and 13.0 oz per 303 × 406 can. The fill weight is defined as the weight of green beans packed in a can. In Experiment II the same fill weights were used plus a 10.5-oz fill weight. The 13.0-oz fill weight was taken to be the practical maximum fill weight possible.

Experiments III, IV, and V were carried out using 1-inch cut green beans. In Experiment III the fill weights were: 11.5, 12.0, 12.5, and 13.0 oz. In Experiments IV and V the same fill weights were used plus a 10.5-oz fill weight.

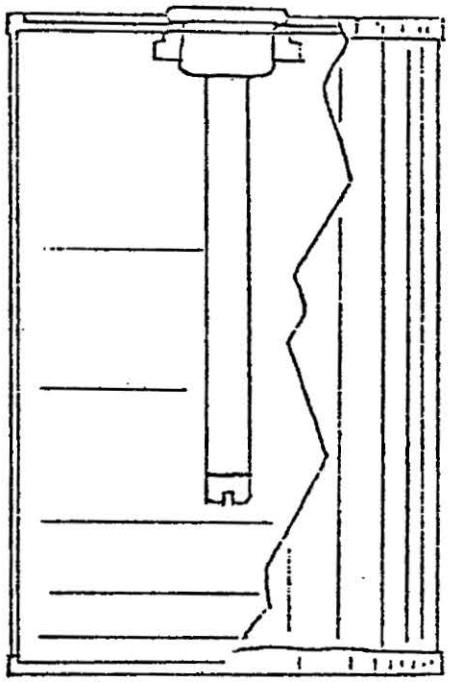

Fig. 1—Cross-section of a can containing a BIU located at the slowest heating zone.

The mean retort temperature was 252.0°F in both Experiments I and II but was different in Experiments III, IV, and V, where the mean retort temperature was 251.5, 252.1 and 250.6°F respectively.

Biological indicator unit tests were carried out in the laboratory at 121.0°C (250°F) to obtain a calibration curve for use in determining F(BIO)-values. These tests were carried out in the University of Minnesota Environmental Sterilization Laboratory.

Spores

Bacillus stearothermophilus spores were used to fill the plastic rod units. The spores were produced in February, 1977, from *Bacillus stearothermophilus*, ATCC 7953, using nutrient agar supplemented with five ppm $MnSO_4$. The spore crop was incubated at 55°C (131°F) for 48 hr. To free the spores from vegetative debris, the spore suspension was insonated using a sonic probe. After insonation, the spore crop was alternately washed with water for injection (USP) and then centrifuged. After cleaning, the spores were suspended in 50X Butterfield's buffer made up with water for injection (USP). The spore suspension was stored at 4°C (39.2°F).

Biological indicator units

The BIUs used in this study were similar to those described by Pflug (1976). These Lot 10 BIUs were prepared in March, 1978. Each rod was filled with about 0.28 ml of spore suspension (5×10^6 spores). Each BIU was numbered and this number used to identify the can in which the BIU was placed and later the petri plates for determining the number of surviving spores.

Experimental procedures followed in calibration of BIUs

The BIUs were calibrated by heating three randomly-selected BIUs for five or six different lengths of time in a miniature retort at 118.0, 121.0, and 124.0°C (244.4, 250, and 255.2°F). One test was

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carried out at 118 and 124°C, and two tests at 121°C. To determine the initial number of spores per BIU, five randomly selected rods were heated at 100°C (212°F) for 15 min in a boiling water bath (spore activation). All BIUs were cooled in an ice water bath and held in it until recovery procedures were started.

A calibration graph and table of the number of surviving spores per BIU as a function of the sterilizing value at the calibration temperature were prepared at each calibration temperature.

The number of surviving spores per BIU for all calibration and field tests was determined using TS (Trypticase Soy) agar, BBL, Lot No. E9DETQ, and standard plate count procedures. Incubation was at 55°C for 48 hr.

Installing biological indicator units in metal containers

To install a BIU in a can, a hole was punched in the end of the 303 × 406 can. An Ecklund receptacle was then installed in the end of the container. Immediately before filling the cans, the plastic rod BIU was screwed into place, as shown in Figure 1, and the can painted red to facilitate recovery.

The BIUs were 75 mm long and inserted along the central axis of the container with the calibrated spores located along the center line of the container. In this location the BIUs should not stir the contents of the container as it rolls through the retort and they are at the farthest distance possible from the container wall. We believe the BIUs were at the slowest heating zone in the container.

Field test procedures

The plastic rod BIUs were carried to the plant in ice water in insulated containers. The BIUs remained in the ice water until they were placed in the cans.

Empty 303 × 406 cans were fitted with BIUs. The cans were hand filled to weight with the appropriate style of drained green beans and then filled with brine to overflowing. The cans were then placed on the filling line ahead of the closing machine where they were sealed mechanically, loaded into the Sterilmatic retort, and heated. Five cans with BIUs were used at each test condition. The initial product temperature measured at the retort was 102°F.

The cans of green beans were heated in FMC Sterilmatic retorts which are continuous agitating machines. The FMC Sterilmatic retort used to heat the French-style green beans was made up of three shells of equal size; two shells were used for heating and one for cooling. The two heating shells were operated at the same temperature. The reel speed was 10.6 rpm. The total time for a can to move through both the first and second heating shells was 15.6 min (process time) and to move through the cooling shell an additional 7.8 min.

The 1-inch cut green beans were heated in a two-shell FMC Sterilmatic retort. The reel speed was 7.3 rpm. The time for a can to move through the heating shell was 11.3 min (process time) and through the cooling shell, 11.3 min.

The operating temperatures used in the several experiments were: I and II, 252.0; III, 251.5; IV, 252.1; and IV, 250.6°F. The retort operating conditions (temperature and pressure) were determined by the mercury-in-glass thermometers and the steam pressure gauges, respectively. Temperature and pressure readings were recorded at intervals of 1.5–2.0 min at each measuring station around the sterilizer. Data collection continued until the cans were in the cooling section. The time the cans entered the machine was noted on the record. The record was used to determine the average heating medium temperature.

Table 1—Fill weight, drained wieght, and F(BIO)-values for French-style green bean tests[a]

Exp. no.	Fill wt. (oz)	Drained Weight Mean (oz)	Drained Weight Coef. of var.	F (BIO) Mean (min)	F (BIO) Coef. of var.
		Series I Experiments			
		Heating Medium Temperature, 252.0°F			
ID	11.5	11.2	0.015	13.2	0.025[b]
IC	12.0	11.6	0.021	12.4	0.047
IA	12.5	12.0	0.014	9.7	0.016
IB	13.0	12.4	0.068	9.7	0.086
		Series II Experiments			
		Heating Medium Temperature, 252.0°F			
IIA	10.5	9.9	0.004	16.3	0.048
IIB	11.5	10.7	0.000	14.7	0.053
IIC	12.0	11.4	0.005	13.5	0.029
IID	12.5	11.8	0.006	11.0	0.024[b]
IIE	13.0	12.2	0.009	9.0	0.140

[a] Results based on five replicates except where noted.
[b] Values based on average of data from four units.

Spore recovery procedures

After the heating and cooling process was completed, the cans containing the BIUs were recovered, the drained weight measured, the cans opened, and the BIUs removed. Using a Vortex mixer, the rods were agitated 15 sec, opened, and the spore suspension was removed using a 0.25-ml glass tuberculin syringe. The sample was either diluted to the appropriate level using phosphate buffer or plated directly into 100-mm petri dishes. Single plates of each dilution were plated. About 30 ml of TS agar was added to each plate. The plates were incubated 36 hr at 55°C and colony-forming units counted.

Analysis of data

The F(BIO)-values were calculated from the plate count data. The number of colony-forming units per plate was multiplied by the appropriate dilution factor to obtain the number of surviving spores per BIU. When we are using BIUs in the laboratory or in the field, we calculate an F(BIO)-value for each BIU by entering the appropriate calibration table or graph with the count per BIU and reading the F(BIO)-value either from the table or from the graph. For each test condition, the mean, standard deviation, and coefficient of variation was calculated for the F(BIO)-values and for product-drained weight.

The temperature response parameters, f_h, that will produce F(250°F z = 12.7°F) were values of 9, 10, 11, 12, 13, 14, and 16 min. These values were calculated using the method developed in this laboratory by R. Holcomb for a j-value of 1.0, a heating medium temperature of 252°F, and initial temperature of 102°F, a cooling water temperature of 55°F, and a z-value of 12.7°F. (The z-value of 12.7°F was used since the F(BIO)-values were determined by spores with this z-value.)

RESULTS

THE MEAN of the F(BIO)-values obtained as a function of fill and drained weight and their coefficient of variation are summarized in Table 1 and Figure 1 for French-style green beans and in Table 2 and Figure 2 for 1-inch cut green

Table 2—Fill weight, drained weight, and F(BIO)-values for 1-inch cut green bean tests[a]

Exp. no.	Fill wt. (oz)	Drained Weight Mean (oz)	Drained Weight Coef. of var.	F (BIO) Mean (min)	F (BIO) Coef. of var.
		Series III Experiments			
		Heating Medium Temperature, 251.5°F			
IIIG	11.5	12.1	0.004	10.4	0.046
IIII	12.0	12.4	0.007	9.0	0.037
IIIE	12.5	12.8	0.006	9.0	0.056
IIIH	13.0	13.1	0.007	8.4	0.026
		Series IV Experiments			
		Heating Medium Temperature, 252.1°F			
IVA	10.5	11.1	0.005	11.8	0.022
IVB	11.5	12.0	0.006	10.8	0.029
IVC	12.0	12.4	0.006	10.9	0.050
IVD	12.5	12.8	0.003	9.8	0.030
IVE	13.0	13.2	0.000	9.8	0.060
		Series V Experiments			
		Heating Medium Temperature, 250.6°F			
VH	10.5	11.2	0.004	10.4	0.031
VI	11.5	12.0	0.005	8.8	0.019
VJ	12.0	12.4	0.004	8.3	0.031
VK	12.5	12.8	0.004	8.0	0.035
VL	13.0	13.1	0.003	7.8	0.015

[a] Results based on five replicates except where noted.
[b] Values based on average of data from four units.

beans. The reported F(BIO)-values are minutes at 250°F (121°C) as measured by spores with a z-value of 12.7°F.

The data indicate that for both green bean products, as the fill weight increased from 10.5 to 13 oz, there was a decrease in the F-value.

The largest fill weight evaluated, 13 oz, required a great

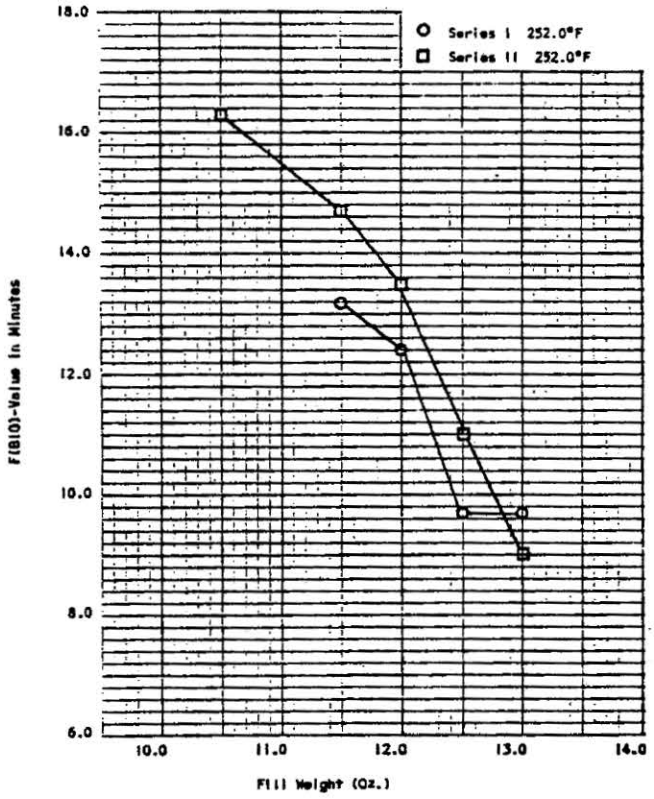

Fig. 2—F(BIO)-value vs fill weight for French-style green beans.

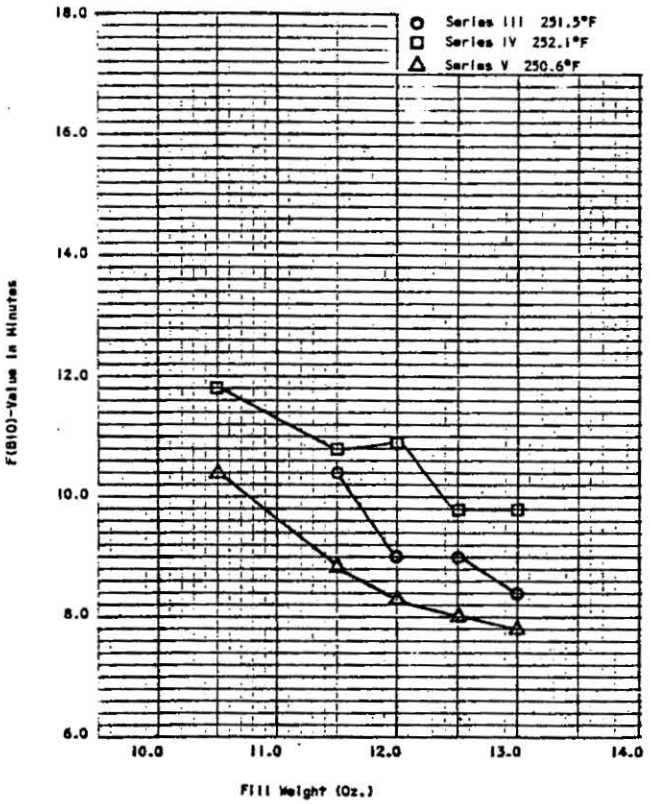

Fig. 3—F(BIO)-value vs fill weight of 1-inch cut green beans.

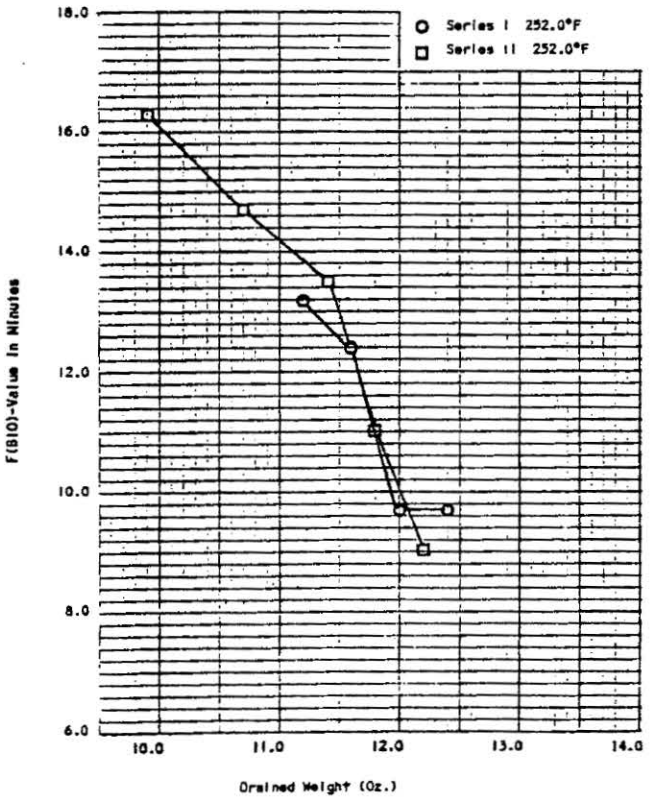

Fig. 4—F(BIO)-value vs drained weight for French-style green beans.

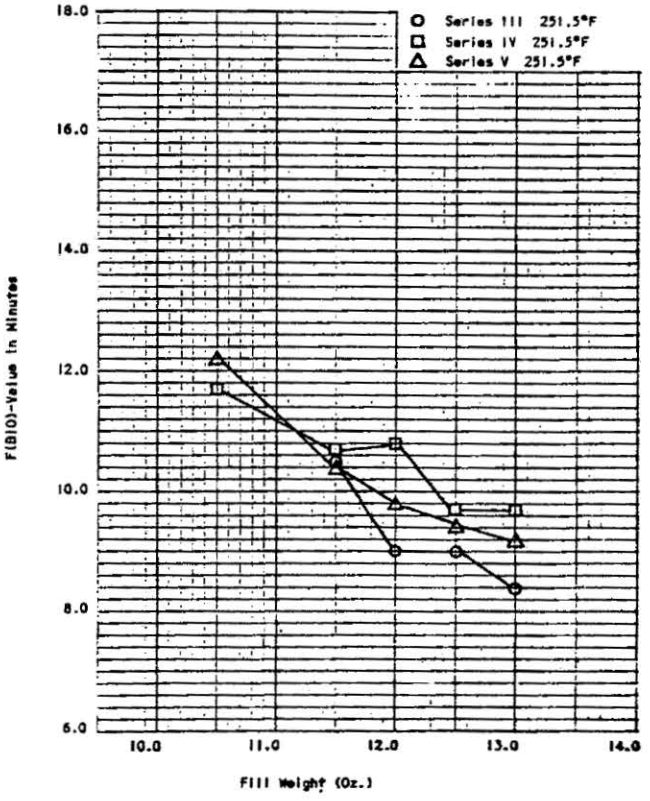

Fig. 5—F(BIO)-value vs fill weight for 1-inch cut green beans adjusted to the same retort temperature of 251.5°F.

Table 3—F(250°F, z = 12.7°F)—values for the data in Experiments III, IV, and V adjusted to the same retort temperature of 251.5°F

Fill wt (oz)	Test series III	Test series IV	Test series V
10.5		11.7	12.2
11.5	10.5	10.7	10.4
12.0	9.0	10.8	9.8
12.5	9.0	9.7	9.4
13.0	8.4	9.7	9.2

Table 4—Calculated temperature response parameter values, f_h, for a range of F(250°F, z = 12.7°F)—values using a heating medium temperature of 252°F and an initial temperature of 102°F

	f_h, min	
F (min)	Process time 11.3 min	Process time 15.6 min
9	3.0	5.7
10	2.6	5.2
11	2.2	4.8
12	1.8	4.3
13	1.3	3.9
14	0.9	3.5
16	0.1	2.7

deal of special effort to put this weight of green beans into the 303 x 406 can. We believe that 13.0 oz fill weight represents a maximum condition, a condition that will not be obtained on commercial packing equipment using the type of mature green beans that are now being commercially processed.

The two French-style green bean experiments were carried out at the same temperature (252.0°F). Comparison of F(BIO) results of the two experiments is interesting in that on the basis of fill weight the F(BIO)-values for 11.5, 12.0, and 12.5 oz are about 1.0 min larger in Experiment II than in Experiment I. However, when the data from the two experiments are compared on the basis of drained weight, there is much closer agreement between the F(BIO)-value results of Experiments I and II (Fig. 4). Relatively speaking, the product in Experiment I had consistently higher drain weight than the product in Experiment II. This phenomenon did not appear in the results of the 1-inch cut green beans where the drain weights were almost identical in the three experiments. We did not plan to relate our studies to raw product characteristics so the raw product history was not obtained; our conclusions are that the variation in drained weight is a raw product attribute and that there was a difference in the raw product in the plant when we carried out Experiment I compared to when we carried out Experiment II.

The three experiments with 1-inch cut green beans were carried out at three different temperatures, 251.5, 252.1, and 250.6°F. The F(BIO)-value data in Table 2 were adjusted downward by 0.6°F for Experiment IV and upward 0.9°F for Experiment V, putting the results of these three experiments all on the basis of 251.5°F. The adjustment was calculated as a relative lethal rate using the lethal rate equation $L = 10^{\Delta T/z}$. The results are tabulated in Table 3 and shown graphically in Figure 5. We can now compare the F(BIO)-value results from the three experiments for fill weights of 11.5, 12.0, 12.5, and 13.0 oz. The F(BIO)-value results of the three experiments appear to agree well within the limits of experimental error.

The calculated f_h-values to produce F (250°F, z = 12.7°F) ranging from 9–16 min are shown in Table 4 for process times of 11.3 and 15.6 min.

DISCUSSION

THE RELATIVELY HIGH F-value delivered in these experiments should probably be assumed normal when sterilizing this type of product in an FMC Sterilmatic continuous agitating processing system. The requirements for public health safety, $F_o \geqslant 3.0$ min, and for preservation against nonpathogenic organisms, $F_o = 5–8$ min, are considerably exceeded in these processes where the F-values are of the order of 10–12 min. Consequently, an increase in fill weight from the specified value to a maximum of 13 oz for a 303 x 406 can processed under these conditions did not reduce the F-value to a point of concern.

The calculated f_h-value shown in Table 4 allows us to make some additional observations on the data that we have gathered regarding the effect of fill weight and product type on processing conditions. While we can make some observations regarding the heating of French-style and 1-inch cut green beans, we are limited in our comparisons because the French-style green beans were heated in a Sterilmatic operating at 10.6 rpm and the 1-inch cut green beans were heated in a Sterilmatic operating at 7.3 rpm.

The data indicate that as the fill weight increased from 10.5 to 13.0 oz for the cans of 1-inch cut green beans (7.3 rpm reel speed), the f_h-values increased from 1.8 to 3.0 min and for the cans of French-style green beans (reel speed of 10.6 rpm), the f_h-values increased from 2.7 to 5.7 min. We do not know the effect of 10.6 vs 7.3 rpm reel speed on the rate of heating, but if we assume that there is no reel speed effect, there is a clear difference between the f_h-values of the French-style and 1-inch cut green beans for the same range of fill weights. The French-style green beans have f_h-values that are larger than the f_h-values of the 1-inch cut green beans.

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