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USE OF IRRADIATION IN THE PRESERVATION OF TRADITIONAL SOUTH AFRICAN FOODS

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Abstract

A variety of traditional African foods are prepared in the home and enjoyed by a large number of consumers. Currently, hardly any of these foods are available commercially. However, these foods are laborious to prepare, not generally available commercially and have a limited shelf life. The application of irradiation (alone) or in combination with other technologies can help solve these problems. The effect of irradiation (0, 10, 20 and 30 kGy at 5 °C) on the consumer acceptability of a traditional South African ready-to-eat (RTE) meal consisting of spinach (morôgo) and sorghum porridge was investigated. The two components of the meal remained acceptable up to a dose of 10 kGy. The limiting factor for using higher doses was the porridge component, especially in terms of texture (too soft) and taste (off-flavour development). Therefore the use irradiation at 10 kGy in combination with different levels of sodium nitrite was proposed to improve the storability of the RTE-meal. Research is in progress investigating the effects of combining mild heat, sodium nitrite and irradiation on the microbiological quality, shelf-life and acceptability of a RTE- meal consisting of spinach (morÔgo) and sorghum porridge. Washing in chlorinated water reduced inoculated *Clostridium sporogenes* spores in spinach by about 2 $\log_{10}$ cfu/g probably because hypochlorites are bacteriostatic. Blanching of spinach after the chlorine treatment did not effect the *C. sporogenes* counts. However, *C. sporogenes* counts increased by about 1 $\log_{10}$ cfu/g during cooking, probably due to the activation of the spores by heat. On the other hand, cooking reduced *C. sporogenes* counts in the porridge significantly (by about 2 $\log_{10}$ cfu/g). Gelatinised starch granules probably protected the spores against heat activation. In both meal components, cooking caused a significant decrease in the final nitrite levels. This may be due to the fact that nitrite can form complexes with other components during heating. Nitrites also probably leached out during the cooking process (for spinach) or evaporated during cooking (for spinach and porridge). Irradiation significantly increased the nitrite levels in the spinach component, probably due to the oxidation of nitrate and other nitrogenous compounds by free radicals. However, the final nitrate levels in the RTE-meal (71 ppm in spinach and 52 ppm in porridge) were much lower than required legally (200 ppm). In both meal components, there was a significant decrease in spores with the use of sodium nitrite, probably because nitrites inhibited microbes by interfering with their metabolic systems. However, after 12 days of storage at 10 °C, an increase *in C. sporogenes* counts were observed in the porridge component. This might be attributed to the fact that the porridge had less sodium nitrite available during storage than the spinach component. Nitrite in combination with irradiation significantly reduced the *C. sporogenes* counts in both the meal components to less than 1 $\log_{10}$ cfu/g immediately after processing. Therefore, the use of higher levels of sodium nitrite (but still within legal limits) in combination with irradiation is recommended for the final phases of this project.

1. INTRODUCTION

Traditional foods such as porridges (ting, phuthu, maqebekoane), gruels (mageu, lesheleshele, motoho wa mabele), relishes (morôgo, achar, linaoa) and meals (likgobe tsa linaoa le poone) form part of our South African culture. They are the staple food of the majority of our people and they are produced from locally grown foodstuffs. However, these foods are laborious to prepare, not generally available commercially and have a limited shelf life. The application of irradiation (alone) or in combination with other technologies can help solve these problems.

The effects of modified atmosphere packaging (MAP) (84.5% N_2 + 15.5% CO_2)-irradiation (target dose of 10 kGy) combination treatments on the safety and microbiological shelf-life of a traditional South African ready-to-eat (RTE) meal consisting of spinach (morÔgo) and sorghum porridge were investigated at 5°C and 37°C respectively (Minnaar, Taylor, Obilana and Duodu, 1998) Irradiation reduced *Clostridium sporogenes* counts (4 $\log_{10}$) and total plate counts (TPC) (3 $\log_{10}$) in the RTE meal significantly. MAP had no effect on the proliferation of *C. sporogenes* during the storage period at 37°C but reduced their proliferation beyond 5 d of storage at 5°C. MAP had a significant effect on TPC at both 5°C and 37°C. The shelf-life of the RTE meal at 5°C was 3 d for the control, 5 d for the MAP alone treatment, at least 7 d for both the irradiation alone as well as the combination treatment. At 37°C, the shelf-life of the RTE meal was less than 1 d for both the control and the MAP alone treatments, 3 d for the irradiation alone treatment and at least 7 d for the combination treatment.

A safe sorghum porridge and spinach RTE meal with a shelf-life of at least 7 d at 5°C using MAP — irradiation combination processing was produced. However, this RTE meal is a low acid food in which *Clostridium botulinum* could grow and produce toxins under favourable conditions. If the cold-chain were broken during distribution and/or retailing, the safety of the meal could be compromised by rapid growth of surviving pathogenic bacteria. From a safety point of view, it was therefore recommended that irradiation should not be combined with MAP conditions (favouring the absence of oxygen in a full barrier packaging material). It was further recommended that either higher dose levels or alternative hurdles (e.g. use of nitrites) should be used to render the RTE-meal microbiologically safe and stable.

2. DESCRIPTION OF RESEARCH CARRIED OUT

2.1 Objectives

Primary objectives:

To develop a system to apply suitable modern food technologies to the manufacture of a RTE-spinach morôgo and thick sorghum meal, and to scientifically assess the quality of this meal. To improve the storability and reduce the preparation time of the RTE-meal.

Secondary objectives:

1. To investigate the effect of irradiation (0, 10, 20 and 30 kGy at 5°C) on the sensory acceptability of the RTE meal.

Depending on the highest dose level at which the meal is still found to be acceptable, one of the following options will be followed:

Option 1 (meal is still acceptable at 30 kGy):

Use of irradiation in combination with mild heating (cooking) to produce a safe food product

- Inoculate raw spinach and sorghum meal with *Clostridium sporogenes* spores.
- Investigate the effects of processing (i.e. washing in chlorinated water – 250 ppm; blanching, cooking and irradiation) on the survival of inoculated spores.

Option 2 (meal still acceptable up to 20 kGy):

Use of irradiation in combination with mild heating (cooking) as well as sodium nitrite to produce a safe food product

- The effect of varying sodium nitrite levels on the inhibition of spores of *Clostridium sporogenes* in the RTE-meal will be studied.

- Inoculate raw spinach and sorghum meal with *Clostridium sporogenes* spores.
- Investigate the effects of processing (i.e. washing in chlorinated water – 250 ppm; blanching, cooking, addition of optimum level of sodium nitrite and irradiation) on the survival of inoculated spores.

2. To select the most effective treatments (alone or in combination) and to determine the microbiological quality and shelf life of the RTE-spinach morôgo and sorghum porridge meal.

2.1 To determine consumer acceptability and preference of the most promising treatments for producing an RTE-spinach morôgo and sorghum porridge.

2.2 Preparation of the RTE-meal
A simplified flow diagram of the preparation and processing of the RTE-meal is given in Figure 1.

2.3 Consumer sensory acceptability of irradiated RTE meal

2.3.1 Objective:

To conduct consumer acceptability tests to establish the sensory cut-off point for the irradiation dose in spinach (morôgo) and sorghum porridge ready-to-eat meal.

2.3.2 Methods:

Consumer acceptability tests were performed for four irradiated spinach meal samples (0, 10, 20 and 30 kGy) in order to establish the most promising irradiation treatment for producing a RTE meal. 50 panellists did sensory evaluation. A 9-point hedonic scale (where 1= Dislike extremely; 5 = Neither liked nor disliked and 9 = Liked extremely) was used and the following characteristics were evaluated: Appearance (spinach); appearance (porridge); texture (spinach); texture (porridge); taste (spinach) and taste (porridge); overall acceptability of the meal.

2.3.3 Results and Discussion:

Table 1 shows the effect of different irradiation doses on the consumer acceptability of the meal. The two components of the meal remained acceptable up to a dose of 10 kGy. The limiting factor for using higher doses was the porridge component. The tasting scores for the porridge irradiated at 20 and 30 kGy were unacceptably low, and the texture of the sample irradiated at 30 kGy was also found to be too soft. Depolymerisation of starch molecules caused the softening effect of porridge at high irradiation dose levels, whereas free radical formation probably resulted in off-flavours in the meal irradiated at the higher dose levels. Based on these results, it was decided that only up to 10 kGy would be suitable for producing an acceptable RTE-meal. Therefore, it was recommended that option 2 would be followed, i.e. where irradiation would be combined with other hurdles (i.e. sodium nitrite).

Young, soft leaves of spinach

↓

Leaves chopped

↓

Rinsed in chlorinated water
(250ppm)

↓

Blanched in two changes of hot water to remove nitrates and oxalates
(77 °C for 6 min)

↓

Cooking of spinach morôgo
(cooked chopped spinach added to simmered canned tomato and onion mix — salt and pepper used as flavourants; preparation time: ca 30 min)

↓

Cooking of sorghum meal (sorghum meal mixed with cold water to form a paste; paste poured into boiling water; stirring to prevent formation of lumps; cooking of watery paste; preparation time: ca 40–60 min)

↓

Packed in polystaene trays and permeable polyethylene bags Sealed
Kept refrigerated overnight (5°C)

↓

Transported to irradiation facility (using insulated boxes)

↓

Irradiated in a ^{60}Co source at refrigerated temperatures

↓

Stored at refrigerated temperatures (5°C)

Fig. 1. Flow diagram of preparation and processing of the RTE — spinach morôgo and thick sorghum porridge meal.

2.4. Effect of different levels of sodium nitrite and irradiation (at 10 kGy) on the survival of inoculated C. sporogenes spores in the RTE-meal

2.4.1 Objectives:

- To study the effect of pre-processing steps (i.e. washing, blanching and cooking for spinach and cooking for porridge) on the survival of inoculated *C. sporogenes* spores.
- To determine the effect of cooking (alone) and irradiation (alone) on added sodium nitrite.

- To determine the effect of sodium nitrite (at different concentrations) alone, and in combination with irradiation at 10 kGy on the survival of *C. sporogenes* spores in the RTE-meal stored at 10 °C for 12 days.

Table 1. Effect of irradiation on consumer sensory acceptability of the RTE-meal[1]

Irradiation Dose (kGy)	Appearance		Texture		Taste		Overall acceptability of meal
	Porridge	Spinach	Porridge	Spinach	Porridge	Spinach	
0	7.26 c (1.93)[2]	7.20 b (1.62)	7.16 c (1.99)	7.12 b (1.59)	6.76 c (2.38)	7.28 b (1.70)	7.20 c (1.35)
10	6.36 b (1.95)	6.74 b (1.72)	6.16 b (2.16)	7.12 b (1.19)	5.70 b (2.44)	7.08 b (1.78)	6.43 b (1.80)
20	5.50 a (2.17)	6.58 b (1.68)	5.64 b (2.24)	6.80 ab (1.50)	4.68 a (2.21)	6.56 ab (1.94)	5.96 ab (1.70)
30	5.30 a (2.10)	6.30 a (1.83)	4.64 a (2.63)	6.30 a (2.21)	3.82 a (2.11)	6.10 a 2.13)	5.41 a (1.91)

1. Mean values with different letters in columns differed significantly from each other ($p<0.05$).
2. Standard deviation in parenthesis.

2.4.2 *Methods:*

Inoculated pack studies were conducted as follows:
A stable *C. sporogenes* spore suspension was prepared according to the methods of Anellis, Berkowitz, Kemper & Rowley, (1972) and Anellis, Shattuck, Rowley, Ross, Whaley & Dowell (1975). *C. sporogenes* DSM 1446 and two locally isolated C. sporogenes strains, i.e. Cl 5 and Cl 10, were used for the suspension.

For each processing treatment, aliquots of the spore suspension (10^7/ml) were inoculated into the washing or cooking water of the sorghum porridge and spinach morôgo components of the meal, respectively. RTE-meal packs were sealed and irradiated at 10 kGy at refrigerated temperatures.

2.4.2.1 *Effect of pre-processing steps*

Preliminary experiments were conducted to determine the effect of washing in chlorinated water (250 ppm of $NaOCl_2$), blanching (in two changes of water at 77 °C for 6 min.) and cooking (mild heat treatment) in spinach morôgo on the survival of inoculated *C. sporogenes* spores (10^7 spores/g). Similar experiments were carried out with porridgere garding the effect of cooking. The effect of cooking and irradiation, respectively, on sodium nitrite was also done using AOAC Method 39.1.21 (AOAC, 1995).

2.4.2.2 *Effect of different levels of sodium nitrite*

The cooked meal components were treated with sodium nitrite alone (0, 50, 100, 150 and 200 ppm) to determine its effect on the survival of inoculated *C. sporogenes* spores (10^7 spores/g).

2.4.2.3 *Effect of sodium nitrite in combination with irradiation*

A combination of irradiation (10 kGy) and sodium nitrite (0, 50, 100, 150 and 200 ppm) was used to determine the optimal treatment combination that would give the most significant reduction of the inoculated spores in the RTE-meal over a period of 12 days at 10°C.

2.4.3 Results and Discussion

The effects of pre-processing on the survival of inoculated spores are given in Table 2.

Washing in chlorinated water reduced inoculated *Clostridium sporogenes* spores in spinach by about 2 $\log_{10}$ cfu/g probably because hypochlorites are bacteriostatic. Blanching of spinach after the chlorine treatment did not effect the *C. sporogenes* counts. However, *C. sporogenes* counts increased by about 1 $\log_{10}$ cfu/g during cooking, probably due to the activation of the spores by heat. On the other hand, cooking reduced *C. sporogenes* counts in the porridge significantly (by about 2 $\log_{10}$ cfu/g). Gelatinised starch granules probably protected the spores against heat activation.

Table 2. Effect of pre-processing on *Clostridium sporogenes* counts (log10 cfu/g)

Pre-processing step	Spinach (log10 cfu/g)	Porridge (log10 cfu/g)
Inoculation of sample	5.00 c	5.00 b
Washing	3.41 b (0.28)	N/A
Blanching	3.09 b (0.24)	N/A
Cooking	4.03 a (0.40)	3.02 a (0.22)

Mean values with different letters in columns differed significantly from each other ($p < 0.05$)
Standard deviation in parenthesis N/A

The effect of cooking alone and in combination with irradiation on added sodium nitrite is provided in Table 3. In both meal components, cooking caused a significant decrease in the final nitrite levels. This may be due to the fact that nitrite can form complexes with other components during heating. Nitrites also probably leached out during the cooking process (for spinach) or evaporated during cooking (for spinach and porridge). Irradiation significantly increased the nitrite levels in the spinach component, probably due to the oxidation of nitrate and other nitrogenous compounds by free radicals (Duodu, Minnaar and Taylor, 1999). However, the final nitrite levels in the RTE-meal (71 ppm in spinach and 52 ppm in porridge) were much lower than required legally (200 ppm). The effect of different levels of sodium nitrite over a storage period of 12 days at 10 °C on *C. sporogenes* counts in the spinach and porridge meal components of an RTE-meal is is illustrated in Tables 4 and 5.

Table 3. Effect of cooking alone and in combination with irradiation on added sodium nitrite in the meal components of an RTE-meal

Before cooking (ppm sodium nitrite)	Sodium nitrite concentration in spinach component[1] (ppm)		Before cooking (ppm sodium nitrite)	Sodium nitrite concentration in the porridge component[1] (ppm)	
	After cooking	After cooking and irradiation[3]		After cooking	After cooking and irradiation
50 a	7.56 b (1.14)[2]	40.14 c (4.07)	50 a	19.20 b (1.66)	19.60 b (1.02)
100 a	9.67 b (1.93)	59.06 c (22.96)	100 a	35.38 b (6.60)	29.89 b (5.09)
150 a	13.48 b (1.68)	67.30 c (25.68)	150 a	38.47 b (5.31)	39.37 b (9.60)
200 a	15.65 (b) (1.68)	71.22 c (27.74)	200 a	49.32 b (8.15)	52.00 b (10.23)

1. Mean values with different letters in rows differed significantly from each other ($p < 0.05$).
2. Standard deviation in parenthesis; 3 Actual irradiation doses for different replicates: 1 (13.8 kGy); 2–10.4 kGy; 3–10 kGy).

Table 4. Effect of sodium nitrite on *Clostridium sporogenes* counts ($\log_{10}$ cfu/g) in the spinach component of RTE-meal stored over a period of 12 days at 10°C

Time of storage (days)	Sodium nitrite levels (ppm)[3]					Time effect[1]
	0	50	100	150	200	
0	4.03	4.10	4.03	3.72	2.86	3.75 a (0.50)
6	5.06	3.79	3.30	3.21	3.22	3.72 a (0.77)
12	4.56	3.46	3.54	3.34	2.80	3.54 a (0.77)
Treatment effect[2]	4.55 d (0.57)	3.78 bc (0.34)	3.62 bc (0.38)	3.42 b (0.55)	2.96 a (0.38)	

1. Mean values with different letters in columns differed significantly from each other ($p < 0.05$).
2. Mean values with different letters in rows differed significantly from each other ($p < 0.05$).
3..Standard deviation in parenthesis.

Table 5. Effects of sodium nitrite alone on *Clostridium sporogenes* counts ($\log_{10}$ cfu/g) in the porridge component of RTE-meal stored over a period of 12 days at 10°C

Time of storage (days)	Sodium nitrite levels (ppm)[3]					Time effect[1]
	0	50	100	150	200	
0	2.96	2.65	2.50	2.43	3.13	2.73 a (0.40)
6	4.74	2.86	2.94	2.47	2.46	3.10 a (0.93)
12	5.65	5.00	3.59	3.12	3.01	4.07 b (1.17)
Treatment effect[2]	4.45 d (1.26)	3.51 c (1.14)	3.01 bc (0.56)	2.67 a (0.46)	2.87 ab (0.53)	

1. Mean values with different letters in columns differed significantly from each other ($p < 0.05$).
2. Mean values with different letters in rows differed significantly from each other ($p < 0.05$).
3. Standard deviation in parenthesis.

In both meal components, there was a significant decrease in spores with the use of sodium nitrite, probably because nitrites inhibited microbes by interfering with their metabolic systems (Jay, 1996). Not surprisingly, higher levels of added sodium nitrite resulted in lower *C. sporogenes* counts. However, after 12 days of storage at 10 °C, an increase in *C. sporogenes* counts were observed in the porridge component. This might be contributed to the fact that the porridge had less sodium nitrite available during storage than than the spinach component. Nitrite in combination with irradiation significantly reduced the *C. sporogenes* counts in both the meal components to less than 1 $\log_{10}$ cfu/g immediately after processing. The gamma D_{10}-values of *C. sporogenes* in the RTE-meal was found to be between 2.58 and 2.60 (Obilana, 1998). Therefore a target dose of 10 kGy would result in a 4 $\log_{10}$ cycle reduction in C. sporogenes counts

2.5 Conclusion

The use of higher levels of sodium nitrite (but still within legal limits) in combination with irradiation (10 kGy) is recommended for the final phases of this project.

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