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Shelf-life of minimally processed Swiss steak

(Daya simpan stik Swiss yang diproses secara minimum)

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Key words: minimally processed, *sous vide*, shelf-life, microbiological quality, sensory evaluation

Abstrak

Stik daging lembu dengan sos cendawan (yang dikenali sebagai "Swiss steak") disediakan sebagai produk "sous vide" yang dipak di dalam beg aluminium laminat. Produk tersebut disimpan pada suhu 0 °C ± 1 °C, dan sampel diambil setiap minggu untuk analisis mikrobiologi dan nilai rasa. Kajian yang dijalankan termasuk kiraan aerob dan penghasil spora mesofil, coliform dan *Escherichia coli*, *Staphylococcus aureus* dan *Clostridium perfringens*. Tiada patogen dikesan dan kiraan bagi organisma lain antara 10^3–10^4 cfu/g. Daya simpan bagi produk didapati sekurang-kurangnya 6 minggu. Keputusan penilaian rasa menunjukkan bahawa produk masih diterima baik pada akhir tempoh penyimpanan yang ditetapkan. Kelembutan dan keberjusan daging meningkat semasa tempoh penyimpanan. Penghasilan stik Swiss sebagai hasil proses minimum didapati berpotensi baik.

Abstract

Beef steak with mushroom sauce (known as Swiss steak) was prepared as a *sous vide* product packed in aluminium laminate bags. The product was stored at 0 °C ± 1 °C and samples were taken weekly for microbiological and sensory analysis. The product was tested for mesophilic aerobes and spore-formers, coliforms and *Escherichia coli*, *Staphylococcus aureus* and *Clostridium perfringens*. None of the pathogens were detected, while counts of the other organisms were in the region of 10^3–10^4 cfu/g. The shelf-life of the steak was found to be at least 6 weeks. Sensory evaluation results showed that the product was acceptable till the end of the targeted storage period. There also appears to be a trend for tenderness and juiciness of the product to improve with increased time of storage. The production of Swiss steak as a minimally processed product appears to have good potential.

Introduction

There is an increase in demand for ready-to-eat and easy-to-prepare types of food by consumers as a result of several factors such as high cost and difficulty in getting domestic help, increasing 2-income families and work schedules, resulting in less time being spent in the kitchen for food preparation. At the same time, consumers are also demanding for more high quality foods such as those that receive minimal heat treatment, contain none or lower levels

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of preservatives and products which are as close as possible to the natural products. In response to these demands, food processors began to look for ways to meet these requirements.

One of the several reduced heat process systems developed is *sous vide*. Bailey (1995) stated that the number of *sous vide* producers in the United States is steadily increasing. This follows the trend in Europe which started about a decade ago. There are several reasons for the increasing demand for such products (Bailey 1995). These include better nutrient retention, extended shelf-life, easy reheating and easy control of portion size.

Basically *sous vide* is a French word which means "under vacuum". Under this system, foods may be pre-treated for example using a mild grilling process for steak or a blanching process for vegetables to improve the products, prior to vacuum packing. Once hermetically sealed in impermeable bags, the product is subjected to prolonged cooking at low temperatures. These temperatures are lower than those used for conventional cooking, and are usually in the range of 65 °C to 95 °C (Peck 1997). At the end of the cooking period, the temperature of the product is lowered rapidly and the product stored at refrigerated temperatures as close to freezing as possible, but normally between 1 °C and 8 °C (Schellenkens 1996; Peck 1997). In Europe, *sous vide* products are usually stored refrigerated while in the United States, they are sometimes kept frozen prior to sale (Baird 1990). French regulations state that *sous vide* products must be held at or below 3 °C (Bailey 1995).

As the product is only given a minimal heat treatment and is stored at refrigerated temperatures, microbiological aspects are of concern. In addition, as chilled foods are more easily subjected to temperature abuse compared to frozen foods, proper control of the preparation, including application of a hazard analysis critical control point system, and strict controls throughout the whole process including storage, distribution and reheating are needed (Baird 1990).

One of the greatest concerns of *sous vide* products is the growth of *Clostridium botulinum.* As the products are packed under vacuum which eliminates oxygen in the hermetically sealed packages, all aerobic microorganisms, including those which can cause foul odours, are unable to grow. Thus there is no indication that the products are spoiled. The anaerobic condition present would then allow the growth of *C. botulinum* and other spore-formers such as *Clostridium perfringens* and *Bacillus cereus*. One of the most common pathogens found in meat is *C. perfringens*. Vegetative cells of *C. perfringens* are destroyed by heating to temperatures above 60 ºC but the spores can still survive and resume growth when conditions are favourable (Cooksey et al. 1993). Similarly spores of *B. cereus* can also survive (Turner et al. 1996). Besides these spore formers, *Listeria monocytogenes* is another pathogen that could be present (Schellenkens 1996).

The objective of this study was to develop a product using the principles of *sous vide* processing, and evaluate the microbiological and sensory qualities during storage.

Materials and methods

Production of the Swiss steak

Frozen topside beef steak was sliced to about 2 cm thick. The slices were then partially grilled to brown the surface. The grilled slices were then individually packed in aluminium laminate bags consisting of an outer layer of polyester, a middle layer of aluminium foil and an inner layer of cast polypropylene. A thermocouple was inserted into one of the bags such that its measuring point was at the centre of the steak. Mushroom sauce, containing thin slices of button mushroom, was heated to boiling, then poured into each bag and the bags vacuum sealed. The bags were then immersed in a water bath controlled to a constant temperature of 80 °C.

Cooking was continued until the internal temperature of the steak reached 80 °C. The bags were then removed from the water bath and immediately placed in iced water to reduce the temperature of the product as rapidly as possible to about 5 °C. The cooled bags were transferred to a controlled temperature cabinet which had been adjusted to 0 °C ± 1 °C. Replicate trials were carried out using similar processing parameters and storage conditions.

Sampling

Prior to storing in the controlled temperature cabinet, one of the bags was taken for microbiological examination to determine the microbial status of the product at the beginning of the storage period. At the same time, another four bags were blast frozen to –20 °C and kept frozen at the same temperature in a freezer for sensory evaluation. At weekly intervals, the process of determining the microbial status of the product from one bag of the blast frozen bags was repeated weekly for up to 6 weeks.

Sensory evaluation

Blast frozen samples kept at –20 °C for up to 6 weeks were evaluated at the same time to compare their eating qualities by a trained taste panel of 10 members (Kramer et al. 1963). The bags containing the frozen product were placed in boiling water for 10 minutes to heat up the products before they were presented for evaluation. The sensory characteristics evaluated were tenderness, juiciness, taste, consistency of sauce, colour and overall acceptability. A nine point hedonic scale, where 1 indicates "dislike extremely" and 9 indicates "like extremely" was used (Larmond 1970).

The analysis of variance (Larmond 1970) of the categorical sensory measurements was performed on an IBM mainframe computer using PROC GLM SAS package (SAS Institute Inc. 1985) and Duncan Multiple Range Test (DMRT) multiple comparison procedure (Hochberg and Tamhane 1987) on all possible pairs of treatment means.

Microbiological examination

Standard methods were used for the microbiological examination of the product (Brown and Baird-Parker 1982; Anon. 1998; Harrigan 1998). Using aseptic techniques, the sample packets were opened and approximately 10 g core samples were taken from the steaks. The samples were blended with 90 mL sterile quarter strength Ringer's solution for 2 min using a Stomacher Lab Blender (Model 400) to give a 10^{-1} dilution. Further 10-fold serial dilutions were made as required using the same diluent. As recommended by Harrigan (1998), the samples were tested for mesophilic aerobes, coliforms, *Escherichia coli*, *C. perfringens* and *Staphylococcus aureus*. In addition, counts of mesophilic spore-formers were also carried out.

Mesophilic aerobes (total viable counts) were plated in Plate Count Agar (PCA) and incubated at 37 °C for 48 h. Counts of spore-formers were determined by giving 20 mL of the 10^{-1} dilution a pasteurisation treatment of 65 °C for 15 min in a water bath before plating as for the total viable counts.

For the coliform counts, the 5-tube MPN method using MacConkey's broth, with incubation for 24 h and 48 h was used. Samples from positive tubes were then inoculated into MacConkey's broth and tryptone water, and incubated at 44.5 °C for 24 h and re-examined at 48 h, if negative the first time. Only samples which were positive for both tests were recorded as positive for *E. coli*.

For the *Staphylococcus* detection, the samples were grown in salt meat broth at 37 °C for 48 h, followed by streaking onto Baird-Parker Agar (BPA). After incubation at 37 °C, the plates were examined for typical colonies after 24 h and 48 h.

Detection of *C. perfringens* was carried out using sulphite polymyxin sulphadiazine (SPS) agar under anaerobic conditions at

37 °C for 48 h. This is a selective agar incorporating iron and sulphite ions and positive colonies form typical black colonies (Brown and Baird-Parker 1982; Roberts 1982).

Results and discussion

Sensory evaluation

Results obtained from duplicate trials showed that all samples evaluated were acceptable, although the degree of acceptability varied with some having significant differences as the storage period lengthened. Generally, the taste panelists gave higher scores for the sample that had the longest storage period as shown in *Table 1* (overall acceptability increased to 7.0 and 6.4 respectively after 6 weeks storage). Important organoleptic characteristics such as tenderness and juiciness of the steak were also given higher scores after 6 weeks storage in both trials. However, significant differences were observed in the tenderness and juiciness scores between the initial sample and the sixth week sample in the first trial only, while the difference in the second trial was not as great. This appears to indicate that as the storage time increases, the steak tends to become more juicy and tender, and was preferred by the taste panelists. On the other hand, although acceptable, there were no significant differences observed for colour, taste, consistency of the sauce and overall acceptability, as judged by the panelists.

Microbiological examination

Microbiological examination of the minimally processed Swiss steak was carried out at weekly intervals over a period of 6 weeks. The results are the average of duplicate samples.

The results showed that for both trials, coliforms, *E. coli*, coagulase positive *S. aureus* and *C. perfringens* were not detected in all samples. The initial mesophilic total viable counts were 3.4×10^4 cfu/g and 1.4×10^4 cfu/g respectively for the two trials. After six weeks chilled storage, the corresponding counts were 7.8×10^3 cfu/g and 4.2×10^3 cfu/g, showing a slight decrease in both cases. At the same time, the counts for the spore-formers were 2.2×10^4 cfu/g and 1.1×10^4 cfu/g respectively for the

Table 1. Mean scores for six sensory attributes of minimally processed Swiss steak (Trial 1 and Trial 2)

Week	Colour	Juiciness	Tenderness	Taste	Consistency of sauce	Overall acceptability
Trial 1						
0	6.8a	6.3b	6.1b	6.7a	6.8a	6.7a
1	6.7ab	6.4ab	7.1ab	6.8a	6.8a	6.7a
2	6.5ab	6.5ab	6.6ab	6.6a	6.6a	6.65a
3.	6.3a	6.5ab	6.5ab	6.5a	6.5a	6.35a
4	6.7ab	6.7ab	6.3ab	6.7a	6.5a	6.6a
5	6.8a	6.4ab	6.2ab	6.3a	6.7a	6.3a
6	6.8a	7.0a	7.2a	6.7a	6.9a	7.0a
Trial 2						
0	6.4a	5.7a	5.1ab	6.3a	6.5a	6.1a
1	6.3a	5.5a	5.0ab	6.4a	6.5a	6.0a
2	6.5a	5.3a	4.4b	6.5a	6.6a	6.3a
3	6.5a	5.4a	4.9ab	6.1a	6.4a	5.9a
4	6.8a	6.0a	5.7a	6.7a	6.5a	6.3a
5	6.6a	5.9a	5.7a	6.5a	6.5a	6.4a
6	6.6a	6.1a	5.6ab	6.4a	6.6a	6.4a

Mean scores within same column followed by same alphabet means not significant (p <0.0 5)

initial sample. After six weeks chilled storage, the corresponding counts were 3.2 x 10^3 cfu/g and 4.1 x 10^3 cfu/g *(Table 2)*.

The aerobic and spore-former counts for both trials throughout the storage period are in the same range and show the same trend as can be seen in *Table 2*. As the product was only pasteurised, there will definitely be organisms surviving as the heat treatment is only adequate to destroy vegetative cells. However, the aim of the pasteurisation treatment is to achieve sufficient internal temperature to destroy all vegetative pathogens and to reduce the levels of non-pathogenic vegetative organisms to a sufficiently low level to ensure the targetted shelf-life. According to Brown and Baird-Parker (1982), a processed material (referring to meat) is considered to be acceptable if the aerobic mesophilic plate count is about 10^4 cfu/g or less after pasteurisation treatment. Thus the results show that the minimally processed Swiss steak had received sufficient pasteurisation treatment as the aerobic counts were in the range of 10^3 to 10^4 cfu/g, and none of the indicator or pathogenic organisms tested for were detected.

Table 2. Microbiological quality of stored Swiss steak

Storage time (weeks)	Sample (cfu/g)	Aerobes (cfu/g)	Spore-formers (cfu/g)
0	T1	3.4 x 10^4	2.2 x 10^4
	T2	1.4 x 10^4	1.1 x 10^4
1	T1	2.1 x 10^4	1.9 x 10^4
	T2	1.4 x 10^4	7.5 x 10^3
2	T1	6.5 x 10^3	8.1 x 10^3
	T2	1.2 x 10^4	7.3 x 10^3
3	T1	1.5 x 10^4	9.2 x 10^3
	T2	8.0 x 10^3	3.7 x 10^3
4	T1	8.5 x 10^3	9.0 x 10^3
	T2	7.5 x 10^3	4.2 x 10^3
5	T1	7.1 x 10^3	9.5 x 10^3
	T2	4.1 x 10^3	3.7 x 10^3
6	T1	7.8 x 10^3	3.2 x 10^3
	T2	4.2 x 10^3	4.1 x 10^3

T1 = Trial 1
T2 = Trial 2
Coliforms, *E. coli*, *S. aureus* and *C. perfringens* were not detected in all samples

The most heat resistant of the non-sporing pathogens is *L. monocytogenes* (Hanlin et al. 1995). According to Gaze et al. (1989), *sous vide* products should be held at 70 °C for 2 minutes to eliminate *L. monocytogenes* and this would be sufficient to eliminate all other vegetative pathogens. Since the Swiss steak was pasteurised to an internal temperature of 80 °C, *L. monocytogenes* will not be able to survive.

This heat treatment however, is not sufficient to eliminate bacterial spore-formers such as *C. botulinum.* Psychrotrophic strains of *C. botulinum* (non-proteolytic B and E) have been reported to grow at temperatures as low as 3.3 °C but mesophilic strains cannot grow below 10 °C (Hanlin et al. 1995). The time taken by psychrotrophic *C. botulinum* to produce toxin has been studied extensively by many researchers (Peck 1997). It was found that at storage temperatures between 2.1 °C and 2.5 °C, growth and toxin production have not been detected up to 90 days. Other studies on the use of additional preservative factors such as pH and salt concentration have also been carried out (Peck 1997). The results show that at a pH of 6.5 with the addition of 0.6% salt in the aqueous phase, no growth of *C. botulinum* was detected in 90 days even when stored at 5 °C, even though the sample had been inoculated with spores of the organism. Similar results were reported by Schellenkens (1996) who used beef and chicken stored at 4 °C. Based on these findings, it can be concluded that there will be no problem with toxin formation by *C. botulinum* as the product is stored at 0 °C ± 1 °C for only 42 days.

As can be seen from the results, the spore-former counts are quite close to the aerobic counts from all samples, thus indicating that most of the surviving organisms are the spore-formers. However, as there is a decrease in numbers during storage, it can be seen that these organisms

are unable to grow under the storage conditions used. According to Turner et al. (1996) and Cooksey et al. (1993), both *C. perfringens* and *B. cereus* spores can be reduced by relatively mild heat treatments, namely pasteurization to an internal temperature of 77 °C and heating in 82 °C water for 16 min respectively. The heat treatment given for the Swiss steak was heating in 80 °C water to an internal temperature of 80 °C. It was found that the time required was at least 43 min. This heat treatment should therefore be more severe than either of the two treatments mentioned. Thus most of the spores of these organisms would have been destroyed. This is supported by the result that *C. perfringens* was not detected in any of the samples.

Studies reported by Roberts (1982) and Rosset (1982) showed that bacterial growth and toxin production of various food pathogens are inhibited at different temperatures *(Table 3)*. Thus none of these pathogens will be able to grow or to produce toxins under the storage conditions used (0 °C ± 1 °C).

As can be seen from the results of the microbiological analyses *(Table 2)*, at the end of 6 weeks storage, the microbiological quality of the product was still very good. There is, thus, a possibility that the shelf-life of the product could be further extended under the storage conditions given and perhaps further improving the sensory characteristics such as tenderness and juiciness of the product. However, as mentioned earlier, commercially most processors are currently giving a shelf-life of between 4 weeks and 6 weeks only for their *sous vide* products. Generally the shelf-life is highly dependent on the initial microbial load of the product and the storage temperature, which is usually between 0 °C and 3 °C (Hanlin et al. 1995).

To maintain safety and product quality of *sous vide* products, Bailey (1995) listed some factors that are currently being adopted by processors and should be followed by intending *sous vide* product manufacturers. These include implementation of a mandatory Hazard Analysis and Critical Control Points (HACCP) programme covering raw material suppliers, processing facilities, distribution and retail locations and government regulations allowing plants to produce such products only if they have proper facilities. In addition, the mandatory use of "super-chill" equipment for storage, distribution and at retail level, mandatory use of time-temperature indicators appropriate to the different shelf-life of products, as well as government regulations based on thermal processing parameters and F values that control the length of the shelf-life that can be placed on the product, should be followed.

Conclusion

With proper control of the processing parameters including the storage and sanitary controls, the study has shown that an acceptable meat product which was processed with reduced or less severe heat treatment can be produced. Besides the above, other characteristics of the product

Table 3. Inhibition of growth and toxin formation of some food poisoning bacteria

Temperature (°C)	Microorganism	Effect on microorganism
3.3	*Clostridium botulinum*	Inhibition of toxin production (type E)
5.2	*Salmonella* spp.	Inhibition of growth
6.5	*Clostridium perfringens*	Inhibition of growth
6.7	*Staphylococcus aureus*	Inhibition of growth
10.0	*Clostridium botulinum*	Inhibition of toxin production (types A and B)
10.0	*Staphylococcus aureus*	Inhibition of toxin production

Source: Roberts (1982); Rosset (1982)

such as pH, water activity, salt concentration as well as the presence of any ingredients that have bacteriocidal or bacteriostatic effect will also have an influence on the shelf-life of the product.

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References

Anon. (1998). *Microorganisms in Foods*, Vol 6. International Commission on Microbiological Specifications for Foods. p. 1–74. London: Blackie Academic and Professional

Bailey, J. D. (1995). Sous Vide: Past, Present and Future. In *Principles of modified atmosphere and sous vide product packaging.* (Farber, J. M and Dodds, K. L., ed.) p. 243-61Lancaster-Basil: Technomic Pub. Co.

Baird, B. (1990). *Sous vide*: What's all the excitement about? *Food Technol*. ***44 (11):*** 92, 94, 98

Brown, M. H. and Baird-Parker, A. C. (1982). The microbiological examination of meat. In *Meat microbiology* (Brown, M. H., ed.) p. 423–521. London and New York: Applied Science Publishers Ltd.

Cooksey, K., Klein, B. P., McKeith, F. K. and Blaschek, H. P. (1993). Post-packaging pasteurization reduces *Clostridium perfringens* and other bacteria in precooked vacuum-packaged beef loin chunks. *J. Food. Sci*. ***58(2):*** 239–41

Gaze, J. E., Brown, G. D., Gaskell, D. E. and Banks, J. G. (1989). Heat resistance of *Listeria monocytogenes* in homogenates of chicken, beef steak and carrot. *Food Microbiol*. ***6:*** 251–9

Hanlin, J. H., Evancho, G. M. and Slade, P. J. (1995). Microbiological concerns associated with MAP and *sous vide* products. In *Principles of modified atmosphere and sous vide product packaging.* (Farber, J. M. and Dodds, K. L., ed.) p. 69–104. Lancaster-Basil: Technomic Pub. Co.

Harrigan, W. F. (1998). *Laboratory Methods in Food Microbiology.* p. 220–1. 3rd ed. San Diego: Academic Press

Hochberg, Y. and Tamhane, A. C. (1987). *Multiple comparison procedures.* New York: John Wiley

Kramer, A., Cooler, J., Modey, M. and Twigg, B. A. (1963). Number of tasters required to determine consumer preference for fruit drinks. *Fd. Technol*. ***17:*** 86–91

Larmond, E. (1970). *Methods of sensory evaluation of food*. Canadian Dept. of Agric. Pub. No. 1284

Peck, M. W. (1997). *Clostridium botulinum* and the safety of refrigerated processed foods of extended durability. *Trends in Food Sci. & Technol*. ***8(6):*** 186–92

Roberts, D. (1982) Bacteria of public health significance. In *Meat microbiology* (Brown, M. H., ed.) p. 319–86. London and New York: Applied Science Publishers Ltd.

Rosset, R. (1982). Chilling, freezing and thawing. In *Meat microbiology* (Brown, M. H., ed.) p. 265–318. London and New York: Applied Science Publishers Ltd.

SAS Institute Inc. (1985). *SAS Users' Guide: Statistics* Version 5 Ed. Cary, NC: SAS Institute Inc.

Schellenkens, M. (1996). New research issues in *sous vide* cooking. *Trends in Food Sci. & Technol.* ***7(8):*** 256–62

Turner, B. E., Foegeding, P. M., Larick, D. K. and Murphy A. H. (1996). Control of *Bacillus cereus* spores and spoilage microflora in *sous vide* chicken breast. *J. Food Sci*, ***61(1):*** 217–9, 234

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