AN ABSTRACT OF THE THESIS OF

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Title:___Vitamin B_6 Retention in All-Beef and Beef-Soy Loaves___

Processed by Two Simulated Foodservice Systems_____

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The effect of 0% (all-beef) and 30% replacement of beef by hydrated

soy protein concentrate (beef-soy) on vitamin B_6 retention in meat

loaves was investigated. Vitamin B_6, moisture, fat and nitrogen contents

were determined in raw meat loaf mixtures, as well as in freshly baked,

held, chilled and microwave reheated all-beef and beef-soy loaves.

Baking time, internal temperature, weight of the loaves, and volume and

weight of the drip were recorded. Retention of vitamin B_6 and heating

losses of the all-beef and beef-soy loaves were calculated, based on

the raw meat loaf samples.

The beef-soy loaves required less time than the all-beef ones to

reach an internal temperature of 74°C in a 177°C oven. Compared to the

all-beef loaves, the weight of the beef-soy loaves was higher (P<0.05)

and the volume of the drip was lower (P<0.05). The all-beef and beef-soy

loaves were similar in fat and nitrogen content. Microwave reheating

lowered (P<0.05) moisture in both all-beef and beef-soy loaves.

Retention of vitamin B_6 in the all-beef and beef-soy loaves was

affected by treatment. In freshly baked loaves approximately 91% of

the vitamin B_6 was retained in the all-beef loaf, and 97% in the beef-soy ones. Additional losses of vitamin B_6 occurred during holding at 95°C for one hour followed by 70°C for 15 minutes: all-beef and beef-soy loaves, respectively, retained 80 and 89%. For the all-beef and beef-soy loaves, respectively, 88 and 94% of the vitamin B_6 was retained after chilled storage at 2.8°C for 24 hours; and 89 and 98% with micro-wave reheating for four minutes. For the freshly baked and held all-beef loaves, 4.3 and 5.7% of the vitamin B_6, respectively, was transferred to the drip; and for the beef-soy loaves 0.6 and 0.8% of the vitamin B_6 was recovered in the drip.

Vitamin B_6 retention in all-beef and beef-soy loaves
processed by two simulated foodservice systems

by

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INTRODUCTION

Since the cost of meat is rising, the use of soy products such as soy protein concentrate (SPC) has increased as a partial replacement of meat in the Type A School lunch and in some other institutional foodservices such as hospitals. In 1971-1972, approximately 23 million pounds of textured vegetable protein were used in the school lunch program; this figure doubled the following year (Butz, 1974).

Several investigators (Nielson and Carlin, 1974; Williams and Zabik, 1975; and Bunch, Matthews, and Marth, 1976) reported wide acceptance of soy in the meat dishes by the consumer. Only one study (Nielson and Carlin, 1974) compared the nutritional quality of all-beef and beef-soy meat loaves. It was found that 58% of thiamin was retained in ground beef products containing SPC as compared to 90% thiamin retained in the all-beef products.

Intentional storage of cooked food between preparation and service has become a common practice in quantity food systems. In the conventional foodservice system, cooked food is usually held a period of time before service. In the cook/chill foodservice system, cooked food is held at 0-3°C for one to three days, reheated before service (Rinke, 1976). Our knowledge of the loss in nutritive values of foods during processing, handling, storage and reheating is limited.

Since meat loaf is popular in the American diet, 30% hydrated soy products is allowed (Food and Nutrition Service Notice, 219). Soy proteins retain fat and moisture. Meat loaf containing 0% (all-beef) and 30% (beef-soy) SPC were selected for this study. All-beef and beef-soy loaves were tested in the conventional foodservice system (after baking and holding) and in the cook/chill foodservice system (after chilling and reheating). A survey conducted by Murphy, Koons and Page (1969) in the 1960's, showed that more than half of 300 school lunches did not meet the nutritional goal for vitamin B_6. Vitamin B_6 is water soluble and is considered heat labile, and is destroyed by ultraviolet light and oxidation (Goodhart and Shils, 1980). The content and retention of vitamin B_6 was the major concern in this study on all-beef and beef-soy loaves.

The yield of food has economic implications for the control of portions in foodservice operations. Therefore, cooking and drip losses were recorded. The percentage of moisture content was determined in the raw and cooked meat loaves, because moisture retention in food has sensory implications and possibly nutritional ones. In addition, the cooking time and internal temperature were recorded. The percentage of fat and nitrogen content were also determined in the raw and cooked meat loaves reported in this thesis.

This investigation was undertaken (1) to observe the vitamin B_6 retention of all-beef and beef-soy loaves when processed in both conventional and cook/chill foodservice systems, and (2) to observe whether or not SPC added to the meat loaves had an effect on the retention of vitamin B_6.

REVIEW OF LITERATURE

I. Background on Vitamin B_6

The term "vitamin B_6" was applied by György in 1934 to the rat pellagra-preventive component of the vitamin B complex found in yeast, liver and rice bran. By 1938, vitamin B_6 was isolated and identified (György, 1971). Vitamin B_6 is the group name, for pyridoxine, pyridoxal, and pyridoxamine, the three free forms of the vitamin (Fig. 1).
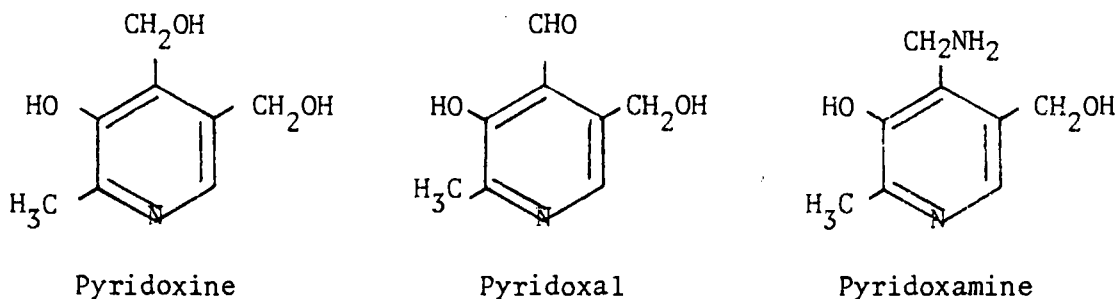
Fig. 1. Chemical structures of the three free forms
         of vitamin B_6

The biological activity of the three forms have been demonstrated in experimental animals and test organisms. In rats, all three free forms of vitamin B_6 have equivalent biological activity, but their stability during processing is variable (National Academy of Sciences, 1980). Among the organisms used for microbiological assay of vitamin B_6 (see review by Storvick and Peters, 1964), by far the most widely used one is Saccharomyces uvarum. Most cultures of this yeast grow with approximately equal efficiency in response to all three free forms of vitamin B_6 (Sebrell and Harris, 1968; Miller and Edwards, 1981).

The coenzyme activities of vitamin B_6 were recognized with the

discovery and identification of pyridoxal-5-phosphate. The phosphory-
lated form of pyridoxamine was subsequently shown to occur naturally
(Goodhart and Shils, 1980).

Physical and chemical characteristics of vitamin B_6

Vitamin B_6 is freely soluble in water. It is unstable when
exposed to light, especially in neutral or alkaline media.

Pyridoxine hydrochloride is a remarkably heat-stable substance
in comparison with most other members of the vitamin B complex.
Because of its heat stability, pyridoxine as well as pyridoxal and
pyridoxamine are not destroyed during acid or alkaline hydrolysis and
extraction. Since most of the vitamin B_6 in nature is protein-bound,
the usual method of hydrolysis is to heat the biological sample with
acid or alkali by autoclaving, in some cases up to five hours, depending
on types of sample.

Vitamin B_6 in food

Vitamin B_6 is widely distributed in foods. Among the most abun-
dant sources of vitamin B_6 are kidney, liver, and muscle tissues with
20-30 µg/g (Orr, 1969). Pyridoxal, pyridoxal-5-phosphate, and pyridoxa-
mine are the predominant forms of the vitamin in animal tissues
(Toepfer et al., 1963; Polansky and Toepfer, 1969; DeRitter, 1976).
Pyridoxine is found in vegetable materials at levels usually equal to
or greater than pyridoxal and pyridoxamine (Sauberlich and Canham, 1973).

Vitamin B_6 occurring in natural food is present in the free or
phosphorylated form bound to protein. For the determination of vitamin
B_6-active compounds, the yeast S. uvarum is well suited for the esti-

mation of total vitamin B_6 in food. The vitamin B_6 values, as micro-biologically assayed, ranged for meats from 3 to 8 μg/g (Polansky and Toepfer, 1969). Raw beef contains 3.3 μg/g of vitamin B_6 (Orr, 1969). The total vitamin B_6 in an unchromatographed sample of raw chuck beef, as reported by Polansky and Toepfer (1969), was 3.0 μg/g.

Milk, not a rich source, contains 0.48 μg/g of vitamin B_6 (Hassinen, Durbin and Bernhart, 1954). Hard whole wheat supplies 4.7 μg/g; whole wheat and white bread contain 1.8 μg and 0.4 μg per gram of vitamin B_6, respectively (Orr, 1969). Except for avocados and bananas, fruits tend to be low in vitamin B_6, containing generally less than 1 μg per gram of vitamin B_6 (Polansky and Murphy, 1966). On the other hand, vitamin B_6, for the most part, in fresh vegetables ranges from 0.5 to 4 μg/g; in the dried beans from 3.9 to 6.2 μg/g (Polansky, 1969).

Vitamin B_6 in diet

Many dietitians and managers of institutional foodservices are concerned about the nutritional adequacy of the foods they serve. The Type A school lunch pattern was designed to provide one-third or more of the Recommended Dietary Allowances (RDA). Murphy, Koons and Page (1969) reported that more than half of the 300 schools they investigated did not meet this nutritional goal for vitamin B_6.

At present, the Food and Nutrition Board of the National Research Council (1980), RDA for vitamin B_6 is 2.0 mg/day for adult females, 2.2 mg/day for adult males, and 1.6 to 2.0 mg/day for grade to adolescents school age.

The average woman in the U.S. may be consuming only between 1.2 and 1.6 mg/day of vitamin B_6 (Donald et al., 1971; Driskell, Geders

and Urban, 1976; Miller, Dow and Kokkeler, 1978). In a study by Kirksey et al., (1978) female adolescents were ingesting 1.24 mg of vitamin B_6 per day, about 79% of the RDA for the 11-14 year old age group. Males usually met the RDA for vitamin B_6 (Driskell et al., 1976).

Deficiency of vitamin B_6
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According to Passmore et al. (1974), vitamin B_6 is so widely distributed in foods that it is extremely rare for an adult human being to show signs of deficiency. Researchers generally agree that 1.0 mg/day of vitamin B_6 is not sufficient and that 2.2 mg/day restores most biochemical parameters to normal, preventing vitamin B_6 deficiency. Thus, an intake of between 1.5 mg and 2.0 mg/day is generally considered adequate.

Snyderman et al. (1953), Coursin (1954), Molony and Parmelee (1954), Tower (1956), and Bessey, Adam and Hansen (1957), reported that certain anemias, sensory neuritis, skin lesions and convulsions in infants may develop when the dietary intake of vitamin B_6 is inadequate. Greenberg et al. (1949) and Vilter et al. (1953) reported that adult human beings receiving diets deficient in vitamin B_6 excreted large amounts of xanthurenic acid in the urine following a test dose of tryptophan. Therefore, vitamin B_6 is required for normal tryptophan metabolism in human beings. Dietary deprivation of vitamin B_6 in an adult may result in depression and confusion (Hawkins and Barsby, 1948). Electroencephalographic abnormalities, followed by convulsions was observed by Canham, Nunes and Eberlin (1964), but not by Grabow and Linkswiler (1969) in experimentally produced vitamin B_6 deficiency

in adult men.

II. The Retention of Vitamin B_6 in Processed Food

Meat, a good source of vitamin B_6, is cooked before consumption.
The effects of cooking and processing on the retention of vitamin B_6
have been published by numerous investigators. Although vitamin B_6
usually is classified as being heat stable, early researches indicated
considerable loss of this vitamin during the cooking of meat.

Henderson, Waisman and Elvehjem (1941), who observed the growth
of rats to determine the vitamin B_6 content of meat and meat products,
reported that, depending on the cooking method, cooked meats retained
only 14-50% of vitamin B_6 in the raw muscle. McIntire, Schweigert
and Elvehjem (1944), using a microbiological method, observed that the
average retention after roasting veal and lamb was 34% and 28%,
respectively. In the boiled lamb the average retention of vitamin B_6
was 34%. In stewed veal and lamb, the retention of vitamin B_6 was 18%
and 16%, respectively; in braised veal, retention was 19%. An average
of 57% of the vitamin B_6 was retained in ham after it had been cured.
Drippings, from the same cooked meat, contained less than 6%
of the total vitamin B_6 in the meat. Both a microbiological yeast
assay and a rat bioassay were employed by Lushbough, Weichman and
Schweigert in 1959, to determine the vitamin B_6 content in different
meats. The percentage retention values ranged from 42 to 67% in muscle,
with 1-13% of vitamin B_6 in the drip. These values were considerably
higher than those reported previously.

Gamma radiation of raw ground beef (approximately 3.0 megarads)
resulted in the destruction of about 25% of the vitamin B_6 (Day et al.,

1957). Richardson, Wilkes and Ritchey (1961) compared the retention of vitamin B_6 in various canned foods preserved by conventional heat treatment and gamma radiation. After fifteen months of frozen storage, beef liver retained 82% and chicken 77% of the original vitamin B_6 content. After the same period of storage, at 24 to 27°C, canned beef liver and chicken retained 36% and 82% of the initial vitamin B_6 content, and irradiated beef liver and chicken retained 56% and 67%, respectively. In 1969, Meyer, Mysinger and Wodarsky determined the average retention of vitamin B_6 in cooked beef. They reported that in oven-braised beef round, 49% of vitamin B_6 was retained in the meat and 34% was transferred to the drip. In oven-roasted beef loin, there was 72% vitamin B_6 retention with 16% recovered in the drip. This report was consistent with the generally accepted heat-stable nature of vitamin B_6.

Wing and Alexander (1972) reported significantly greater retention of vitamin B_6 in chicken breasts heated for 1.5 minutes in a microwave oven than in those heated 45 minutes in a conventional oven. Bowers, Fryer and Engler (1974a, b) used turkey and pork muscles cooked in microwave and conventional electric ovens. The turkey cooked in the microwave oven had more vitamin B_6, calculated on a cooked weight basis, but differences were not statistically significant when calculations were on a moisture-free basis. The pork muscle cooked by either method was not significantly different on the basis of cooked weight. Calculated on the basis of dry weight, however, samples baked in the microwave oven contained slightly less vitamin B_6 than those baked in the conventional oven.

Engler and Bowers (1975a) reported that turkey breast and thigh

muscles roasted from the frozen, partially thawed or the thawed states contained significantly less vitamin B_6 than the same muscle in the raw state. These results indicated that the vitamin B_6 is either transferred to the drip during cooking or is destroyed by the particular heat treatment employed. The other research, done by the same authors (Engler and Bowers, 1975b) had studied the effect of reheating and holding on the vitamin B_6 content of turkey breast. They found that when vitamin B_6 was calculated on the basis of cooked weight, no significant differences were observed among treatments. However, when calculation was on a moisture- and fat-free basis, freshly roasted meat contained significantly more ($P<0.05$) vitamin B_6 than reheated or held meat. Bowers and Craig (1978), using column chromatography with Dowex 50 W-X8 (k^+) to separate the three forms of vitamin B_6, found that pyridoxine and pyridoxal were higher in the raw turkey muscle than in the cooked; and that pyridoxamine was higher in the cooked than in the raw muscle. No significant differences were found in the sum of the three forms of vitamin B_6 or in total vitamin B_6 between cooked and raw muscle.

In studies using other types of products, the retention of vitamin B_6 was variable. A review of the stability of vitamin B_6 in milk in many different heat treatments has been published by Woodring and Storvick (1960). They concluded that pasteurization, drying and homogenization did not appreciably change the vitamin B_6 content in milk. Sterilization and evaporation lowered vitamin B_6 values; irradiation and storage may further decrease the vitamin B_6 content in milk. Hassinen, Durbin and Bernhart (1954) reported that the vitamin

B_6 remaining in spray-dried milk products ranged from 69 to 89% of the initial amount in milk. Hodson in 1956 proposed a mechanism to explain this loss of vitamin B_6 during processing and storage of evaporated milk. He observed that pyridoxal and pyridoxal phosphate in milk were bound to protein or amino acids, and then converted to pyridoxamine and other unknown forms of vitamin B_6 which were less readily available or less measurable by microbiological assay.

For vegetables, Schroeder (1971) reviewed data from the literature and calculated that the losses of vitamin B_6 in canned vegetables was between 57 to 77%, and in frozen vegetables from 37 to 56%. Studies on vitamin B_6 retention during drying were done by Holmes et al., (1979). Losses of vitamin B_6 in home-dried vegetables and berries were between 4 and 41%; tomato puree retained 79%; unblanched green beans, 75%; zucchini squash, 92%; boysenberry leather, 90.5%; and raspberry leather had the greatest retention of vitamin B_6 at 96%.

In cereals, in a study by Bunting (1965), the storage stability of naturally occurring vitamin B_6 plus added pyridoxine hydrochloride was 90 to 95% in corn meal and 100% in macaroni. Similar retention of vitamin B_6 in pyridoxine-enriched flour and cornmeal after storage was reported by Cort et al. (1976).

Losses of vitamin B_6 may be caused by heat destruction and/or leaching into the cooking medium. Factors which may affect cooking losses are the method of cooking (Henderson et al., 1941; McIntire et al., 1944; Day et al., 1957; Meyer et al., 1969; Wing and Alexander, 1972; Bowers et al., 1974; Engler and Bowers, 1975), the internal temperature reached (Hassinen et al., 1954; Davis, Gregory and Henry,

1959; Richardson et al., 1961), the length of the cooking period (Engler and Bowers, 1975), and the volume of water used (Daoud, Luh and Miller, 1977; Raab, Luh and Schweigert, 1973). Additional variables are the frozen or thawed status of the meat, its size and shape, and the amount of surface area exposed to oxygen (Engler and Bowers, 1975). In various types of foods, the proportion of pyridoxine to pyridoxal and pyridoxamine, as well as the extent of interconversion among the three forms during processing (Gregory and Kirk, 1977, 1978) may account for the wide variation in the retention of vitamin B_6.

Thus, it appears that the chemical composition of the food in addition to processing conditions, affects the net retention of vitamin B_6. The bioavailability of vitamin B_6 in foods may be significantly affected by thermal processing (Gregory and Kirk, 1981).

III. Concepts of Foodservice Systems

Foodservice systems

There are three major foodservice systems: conventional, convenience, and automated. The conventional foodservice system now generally pertains to preparing meals on the premises from raw foods prior to each meal. The convenience foodservice system is usually divided into several groups, such as for total convenience food, chilled food, frozen food, and ready food. Totally automated systems begin after the diet order and the diet information have been recorded on punch cards and end when the patient has received his meal. To accomplish this, production, packaging, assembly, transportation, and distribution of food must be completely automated (Rinke, 1976).

For the project presented in this thesis, we chose the conventional system and cook/chill food system, one of the convenience foodservice systems. Fig. 2 presents a flow chart illustrating the sequence of operations in a cook/chill system compared with those of the conventional system. Food storage, preparation, cooking and portioning are common to both systems.

Holding methods of the conventional foodservice system

In a conventional foodservice system, it is necessary for all operations to flow in sequence from the storage of purchased food to the service of the cooked food, and, in many catering situations, it is also necessary to store the cooked food in a warming oven (warmer) for some time before service (Glew, 1973). One of the major problems in this system is how to provide food at a proper temperature to customers.

Hot holding

In many systems "hold hot" equipment is needed to insure a steady supply of ready food to the serving area during the meal period (Livingston, 1968). Equipment used to hold food for servive must be carefully checked. Kahrl (1973) said that if the temperature is too high, the food will continue to cook; if too low, it will be cold when served or microorganisms will grow. The so-called danger zone for food, as described by the U.S. Public Health Service and other people who have studied effects of temperature on the growth of microorganisms is 45° to 140°F (7.2° to 60°C). For ease in remembering, the 40° to 150°F (4.4° to 66°C) range is suggested as a good zone for

FOOD STORAGE

↓

PREPARATION

↓

COOKING

PORTIONING

↓

HOLDING

CHILLING

↓

CHILLED STORAGE

↓

PORTIONING

↓

REHEATING

HOLDING ⟶ SERVICE ⟵ REHEATING
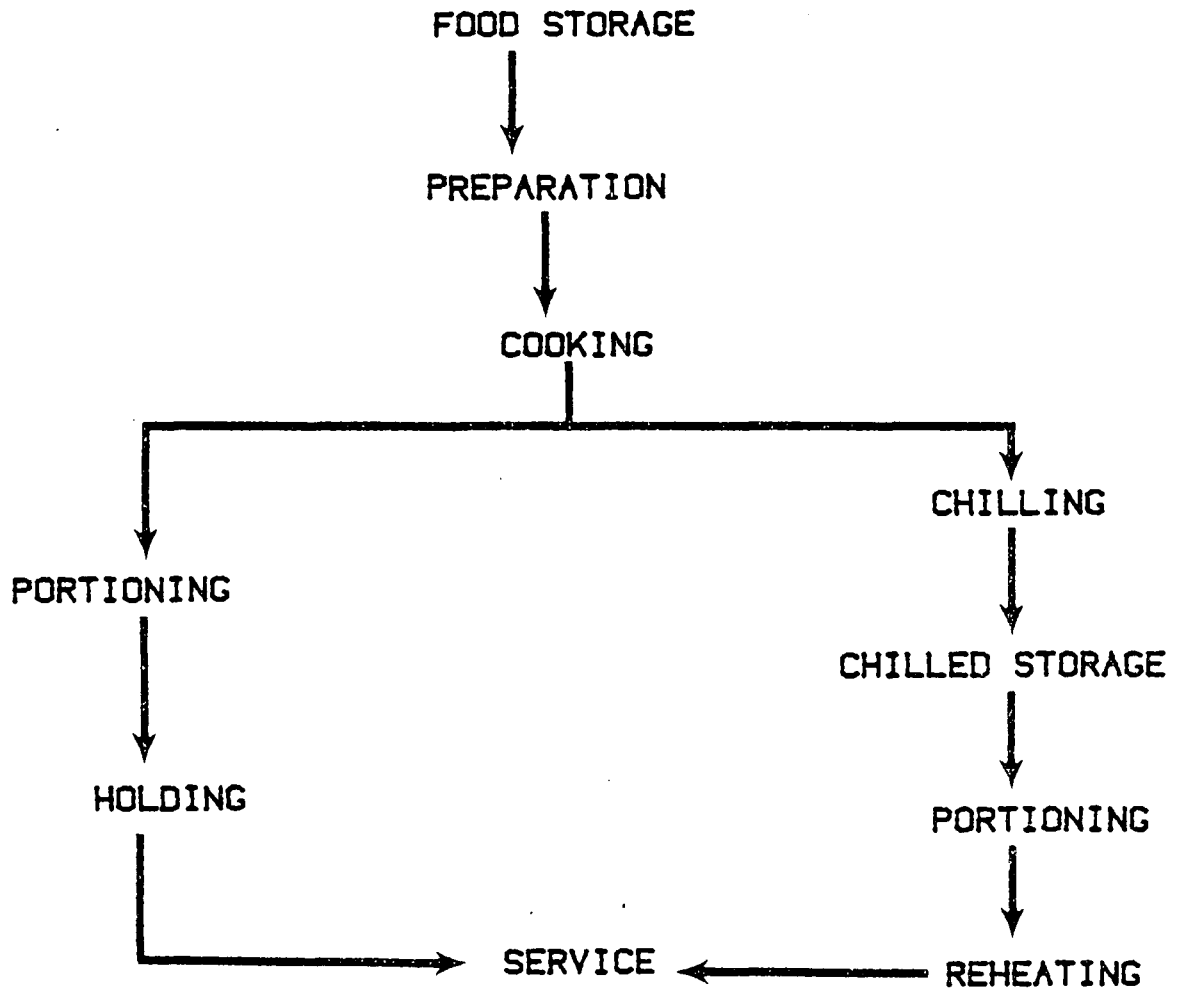
Figure 2. Comparison of conventional (left) and
cook/chill (right) foodservice systems
(Adapted from Glew, p. 28, 1973)

foodservice people to follow, allowing for some inaccuracy in tempera-
ture measuring devices and equipment (Eshbach, 1979).

Hot serving

Holding food on a steam table, hot cabinet, or under infrared
warming lamps for extensive periods of time will downgrade its quality
by altering factors such as texture, flavor, color, and nutritional
content, and also cause some shrinkage. Foods will become mealy,
mushy, soggy, or dried out (Eshbach, 1979; Thormer and Manning, 1976).

Nutritional value and microbial spoilage

A few studies were reported about the retention of some vitamin B
complex in meat during holding. Westerman (1948) found that 91% of
the thiamin was retained, when sliced roast pork was held for 30
minutes over rapidly boiling water. Erickson and Boyden (1947) reheated
turkey and held it on a steam table; they concluded that this institu-
tional practice had little destructive effect on thiamin or riboflavin.
Boyle and Funk (1972) reported thiamin loss of 21.2% when beef was
sliced and served immediately, compared with 20.8 and 23.5% loss for
unsliced and sliced beef, respectively, held for 90 minutes over dry
heat. Relatively large amounts of thiamin, riboflavin, and ascorbic
acid may be lost from vegetables held on a steam table (Head, Weeks
and Gibbs, 1973; Nagel and Harris, 1943; Wood et al., 1946; Munsell
et al., 1949).

Little information was found about vitamin B_6 losses during
holding. The only study, which was mentioned previously, was made by
Engler and Bowers in 1975; these workers reported that the held turkey

breast had significantly lower vitamin B_6 content than the freshly roasted samples when calculated on a moisture- and fat-free basis.

In addition, microbial spoilage may become a problem (Thormer and Manning, 1976). Eshbach (1979) recommended that food not be held more than four hours, and preferably no longer than two hours. Besides time and temperature, humidity can also be controlled in many holding units to produce better food.

Cook/chill foodservice system

In many respects, the chilled food concept functions like a modernized conventional foodservice system (see Fig. 2). The major difference is that all foods are prepared one to three days in advance. Efforts are made to ensure that the food reaches an internal temperature of at least 80°C during cooking. Then the hot food is quickly chilled and kept refrigerated at 3°C or lower. Prior to service, the food is taken out and reheated by various methods, such as microwave energy, integral heat, or convection heat (Rinke, 1976; Livingston, 1972).

The advantages of the cook/chill food system are improved quality of food, increased productivity of foodservice employees, and decreased food and labor costs. Also, foods can be served at their proper temperatures (Koncel, 1976; Kaud, 1972; McGuckian, 1969). However, as the food is not served fresh, quality must be controlled through very precise microbiological audits and taste testing (Koncel, 1976). Also, a correct reheating procedure must be followed to insure properly heated food (Glew, 1973).

Chilled storage

Several refrigerated holding systems have been described by Keskinel, Ayers and Snyder (1964), Sato and Hegarty (1971). Glew (1973) said that at temperature between 2°C and 5°C (35° to 41°F), the growth of most microorganisms is very much retarded, but not entirely stopped. Chilled food can be used up to 48 hours and even 72 hours after it has been cooked and chilled. Some nutritional and palatibility losses occur, depending on such factors as time, temperature and packaging materials (Lachance, Ranadive and Matas, 1973).

Reheating

Before service to the consumer, chilled food must be reheated to 80°C (176°F) if it is to be served hot. Methods for reheating precooked chilled food involve the use of:

(1) dry heat, such as hot air or radiant heat,

(2) moist heat, such as steam or hot water,

(3) microwave heating.

The use of microwave oven reheating is gaining widespread acceptance (Glew, 1973) and was chosen for our study presented in this thesis.

The heating time of foods in the microwave oven depends on the temperature, consistency, shape, and quantity of the food, and type of container. This method reduces the possibility of flavor deterioration, texture changes, loss of nutrients, and unappealing appearance (Glew, 1973).

Reheating and warming table operations slowly destroy nutrients, primarily through oxidative changes (Harris and Von Loesecke, 1975). In such operations, losses of thiamin could range from 4 to 72%;

riboflavin from 8 to 77%; and ascorbic acid from 0 to 94%. For most fruits and vegetables, loss in vitamin content due to reheating of processed products ranges from 20 to 50%.

Thus, in foodservice operations, duration of cooking and storage, and the time before serving may vary considerably, leading to variations in moisture content and in retention of water-soluble and heat-labile nutrients. This problem is important in interpreting the results of dietary surveys and in providing the proper nutrient requirements to consumers.

IV.   Research on Meat Loaves

Meat loaf was chosen for the research presented in this thesis, because it is a common menu item in the American diet, and, in comparison with some other foods, contains only a few major ingredients, and it is relatively compact and homogeneous. This homogeneous character was desirable for this study to eliminate as much variation as possible that could occur in recording temperatures, nutrient analysis and making other evaluations (Bunch, Matthews and March, 1976).

Use of meat substitutes

Critical meat shortages of 1973 and current high cost of meat have caused many foodservice administrators to increase the use of meat substitutes in their operations (Phillips, 1973). The U.S. Department of Agriculture's Food and Nutrition Service issued Notice 219 (1971, February 22) which permitted the use of rehydrated textured vegetable protein products to replace up to 30% of the meat or meat alternate portion in the Class A School Lunch menu. Approximately 23 million

pounds of textured vegetable protein (hydrated weight) were used in the school lunch program during the 1971-1972 school year; this figure doubled the following year. Since this approval of the use of textured vegetable protein products, there has also been a tremendous increase in their use in hospitals and other institutional foodservices (Butz, 1974).

Characteristics of soy proteins

Soy is the leading source of vegetable proteins, and soy derivatives are currently being introduced as components in meat dishes in the form of soy protein isolates, soy protein concentrates, soy flours and soy grits (Rakosky, 1970). When added to meat, the soy products can contribute flavor, increase juiciness, help to retain shape, and provide economical protein (Rakosky, 1974; Wolford, 1974; Judge et al., 1974; and Wolf, 1970).

Since soy proteins are hydrophilic, they have the ability to absorb and retain water. Another important function of soy proteins is their ability to bind fat (Williams and Zabik, 1975). As had been expected, the incorporation of textured soy protein resulted in a decrease in total cooking losses, a subsequent decrease in cooking drip, and a possible decrease in volatile losses (Williams and Zabik, 1975).

Experimentation with meat loaves

Some early studies were made in the effect of cooking and storage on the quality of meat loaves. Most of these studies dealt with microbial growth and sensory evaluation.

Kylen et al. (1964) tested the palatability of beef and ham loaves,

and the retention of thiamin in these loaves cooked in microwave and conventional ovens. Nielson and Carlin (1974) evaluated various aspects of frozen raw or precooked all-beef loaves, and precooked beef-soy loaves with and without an antioxidant. The storage period was zero, two, four, or six months at -20°C. The beef-soy loaves resulted in a 50% reduction in cooking loss compared with the all-beef loaves. The eating quality of the all-beef loaves was not affected by storage, while the soy flavor in the beef-soy loaves was pronounced. The moisture content of the precooked, reheated loaves was significantly lower for the beef-soy loaves than for the all-beef loaves. Storage did not affect the fat content, but the beef-soy loaves retained more fat after cooking. After the loaves had been precooked and reheated, thiamin retention was approximately 90% for the all-beef loaves and 58% for the beef-soy loaves. The explanation by the authors for the lower retention of thiamin in the beef-soy loaves was that the synthetic thiamin added to fortify soy protein is more heat labile than naturally occurring thiamin.

Zallen, Hitchcock and Goertz (1975) studied the effects of chilled holding on the quality of beef loaves. They found statistically significant differences between the freshly prepared beef loaf and the stored loaf. The freshly prepared beef loaf had a shorter heating time, less cooking losses, higher moisture content, lower thiobarbituric acid (TBA) scores, and higher taste panel scores. Pasteurized loaves were not significantly different from refrigerated ones in eating quality. Over the nine-day storage period, TBA scores increased and the taste panel scores decreased significantly. One of the conclusions by these authors was that refrigerated holding systems for cooked

food may offer economic advantages to a foodservice system and also require fewer personnel.

Williams and Zabik (1975) investigated the effect of including rehydrated textured soy protein on the characteristics of ground beef, pork and turkey loaves. The substitute of 30% of the meat by soy did not seem to adversely affect the quality of the meat loaves. No difference was found in the total lipid content of the cooked 0% and 30% soy meat systems. However, the 30% soy-substituted product appeared to have a slightly lower TBA value during refrigeration and frozen storage.

Bunch et al. (1976) investigated the chilled foodservice system in a hospital, and reported the acceptability of beef-soy loaves. The loaves contained 25% rehydrated textured soy crumbs, and after having been precooked, the loaves were stored at ±3°C for 24, 48, and 72 hours. Overall acceptability scores for the final product were almost identical, regardless of the duration of the chilled storage. As for microbiological characteristics, the aerobic bacteria greatly increased during chilled storage. After the loaves had been reheated in a microwave oven, only part of the viable bacteria were killed due to the short heating time.

Bobeng and David (1978) utilized Hazard Analysis Critical Control Point (HACCP) models for quality assessment of beef loaves. They found that the scores for overall acceptability of beef loaves in the conventional system were significantly higher (p<0.05) than for those of the cook/chill and cook/freeze systems. Thiamin retention was not significantly different among the systems. Dahl and Matthews (1979)

varied internal end temperature (ET) of beef loaf after initial cooking
(from 45° to 90°C) in a simulated cook/chill system. They reported
that use of an ET of less than or equal to 60°C for initial cooking
increased yield, moisture content, and possibly nutritive value of
beef loaf after microwave heating.

MATERIALS AND METHOD

Ground beef was made into meat loaves containing either 0% or
30% rehydrated soy protein concentrate (SPC) based on the weight of
meat. The preparation of all-beef and beef-soy loaves simulated
product flow of hot entrees in conventional and cook/chill foodservice
systems (Fig. 2).

The all-beef and beef-soy loaves were tested: (1) before baking;
(2) immediately after baking; (3) after holding baked loaf at 95°C for
one hour followed by holding at 70°C for 15 minutes; (4) after chilling
baked loaf at 3°C for 24 hours; and (5) after reheating in a microwave
oven. Moisture, fat, nitrogen and vitamin B_6 contents were deter-
mined in the meat loaves submitted to these treatments. Preliminary
studies were done to standardize the procedures for food and equipment
handling as well as to develop the sampling methods that were to be
controlled during the three replications (blocks) of the experiment.

Ingredients

For each replication, ten pounds of frozen ground beef, five
packages of two pounds each, were purchased from the Meat Laboratory
at Oregon State University three days before the meat loaves were
prepared. After delivery from the Meat Laboratory, the frozen ground
beef was held at -16°C overnight, then thawed at 1°C two days before
the loaves were fabricated.

After the ground beef was completely thawed, it was mixed five
minutes in a floor-mixer[1] at the lowest speed, twice, a total of ten

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[1]Floor-mixer: Hobart Model A200

minutes. Then three 40-gm samples were removed from the batch to obtain the values for the fat, moisture, nitrogen and vitamin B_6 content that were representative of that lot of ground beef. Dried egg powder, non-fat dry milk, dried bread crumbs, salt and soy protein concentrate were purchased all at one time as a total lot for the entire research project.

Procedure for making meat loaves

The formulas for producing the all-beef and beef-soy loaves were slightly modified from those given by Nielsen and Carlin (1974). Dried egg powder was used instead of fresh egg in this experiment. The formulas are shown in Table I.

The ingredients of each meat loaf were combined by manual and mechanical mixing to assure uniform distribution. The same floor-mixer was used, and the procedure was:

(1) mix egg powder with water at speed one for one minute,

(2) add bread crumbs, salt, non-fat dry milk and water, then mix one minute at speed one,

(3) rehydrate soy protein concentrate with water and allow to stand for five minutes, then add to the mixture and mix at speed one for one minute (omit this step for all-beef loaves),

(4) add ground beef and mix two minutes at speed one, then scrape the mixture around the beater, and mix by hand ten beats, follow by mixing one minute at speed one, two more times.

After all-beef and beef-soy loaves were mixed, three 40-gm samples of each raw meat loaf mixture were randomly taken from the bowl of the

Table I. Formulas for all-beef and beef-soy loaves

Ingredients	All-Beef		Beef-Soy	
	Total Amt. Mixed	Amt. in one loaf	Total Amt. Mixed	Amt. in one loaf
	g	g	g	g
Ground beef[a]	2592	516	1812	361
Hydrated SPC Fortified SPC[b]	0	0	312	62
Tap Water	0	0	468	93
Reconstituted Egg Egg powder[c]	68.4	14	68.4	14
Tap Water	191.6	38	191.6	38
Non-fat dry milk	56	11	56	11
Dry bread crumbs	304	60	304	60
Tap water	784	156	784	156
Salt	24	5	24	5
Total weight	4020	800	4020	800

[a]Ground beef:

	Block I	Block II	Block III
Moisture (%)	59.7	53.3	53.1
Fat (%)	23.2	31.1	31.8
Nitrogen (%)	3.0	2.9	2.9
Vit. B_6 (μg/g)	2.2	2.2	2.4

[b]"SPC" stands for soy protein concentrate; PROCOON TM2000 manufactured by A. E. Staley manufacturing company, Decatur, Illinois 62525. The vitamin B_6 value of SPC is 1.05 μg/g; Nitrogen value is 11.5%.

[c]"Gold.n. Eg" Egg powder by Wilsey Foods, Inc., Los Angeles, California. The vitamin B_6 value of egg powder is 1.43 μg/g.

mixer for moisture, fat, nitrogen and vitamin B_6 determination.
The meat loaf mixture was then packed into four preweighed 20 cm
by 9.9 cm by 5.4 cm pans. The net weight of each raw loaf was 800 gm.
Each loaf pan was covered with waxed paper, and pressed with a weight
of 800 gm for five minutes to obtain uniform packing in each loaf.
The loaves remained in the same pans for baking and storage. Before
baking, all loaves were held at 3°C for one hour to equalize the
internal temperature.

Baking

For each replication, four loaves of the same kind were removed
from the walk-in refrigerator and baked uncovered in a preheated
institutional electric oven[2] which was regulated at 177°C. During
baking, the temperatures of the four loaves were monitored by meat
thermometers inserted in the geometric center of each loaf. When the
internal temperature of each loaf reached the desired temperature,
74°C, that loaf was removed from the oven. Immediately after baking,
the loaves were weighed. Then the drip was poured out into graduated
cylinders for measurement of aqueous and lipid fractions, and the meat
loaves were weighed again. Three of them were loosely covered with
waxed paper and allowed to cool one hour at room temperature.

Holding

The fourth one for conventional foodservice simulation was cut
into six pieces, replaced in a Pyrex pan, covered with aluminum foil

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[2]Institutional electric oven: Despatch Oven Co., Model 150-R

and held at a 95±3°C in a covered waterbath for "hot holding" 60 minutes. After this the meat loaf was removed to another 70±5°C, uncovered waterbath to simulate "hot serving." At this period, the meat loaf was uncovered in the waterbath for 15 minutes. Then it was removed and reweighed.

Chilling

After one hour cooling at room temperature, two of the loosely covered meat loaves were covered with aluminum foil and placed in the same walk-in refrigerator for 24 hours chilled storage. To compare the effects of refrigerated storage and reheating on the loaves, one cooked loaf which had been in chilled storage was taken out of the refrigerator and analyzed directly. The weight of the loaves was recorded before and after the storage treatment at 2.8°C.

Microwave reheating

Following the chilled storage, eight equally sized portions were cut from the whole loaf. Four randomly selected portions from each of the two kinds of meat loaves were placed individually on a pre-weighed pyrex plate. The plate was placed in the center of the micro-wave oven[3] and reheated four minutes. After heating, the portions of meat loaf were allowed to set for two minutes at the ambient tempera-ture of the microwave oven to provide time for temperature stabilization. Reheating times to achieve a final temperature of 55°C were established by prior study, and the time of microwave heating was monitored auto-

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[3]Microwave - Sharp Electronics Corp., Model No. R-6770

matically. Weights of the four portions of meat loaf before and right after microwave reheating were determined.

Sampling of meat loaf

A homogeneous mass was made by grinding one whole loaf with a meat grinder, then three 40-gm samples were taken and frozen storage in plastic bottles until analyzed.

Calculations

Total heating loss was calculated as the difference between raw weight and cooked, drained weight. Drip loss was the difference between the cooked weight and the cooked, drained weight. The difference between total heating loss and drip loss represented volatile loss. Following holding of the loaves and microwave reheating of the stored loaves, the same procedures were followed to determine losses due to holding and microwave reheating. Also, after storage in the refrigerator, loaves were weighed to determine storage loss.

Nutrient Analyses

Moisture

Duplicate samples of each loaf were dried at 60°C in a vacuum oven to a constant weight, according to a modification of the procedure of the Association of Official Analytical Chemists (1975). Percent weight loss of the samples from the drying process was determined as percentages of total moisture content.

Fat

Duplicate samples of each loaf were used to estimate the fat

content by a chloroform-methanol extraction method proposed for foods by Southgate (1971).

Nitrogen

Total nitrogen of the duplicate samples of each loaf was measured by the boric acid modification of the Kjeldahl method by Scales and Harrison (1929).

Vitamin B$_6$

Total vitamin B$_6$ content of the meat loaves and drip was determined by the method of Toepfer and Polansky (1970) based on the growth response of the yeast S. uvarum. A standard curve with pyridoxal was used to calculate the amounts of total vitamin B$_6$ in the samples. For each treatment the unit was sampled in duplicate. Bound vitamin B$_6$ was released by autoclaving a two gram sample in 200 ml 0.055N hydrochloric acid at 102 K Pa for five hours. Five dilutions of each sample were prepared, and vitamin B$_6$ in each dilution was determined in triplicate. A Bausch and Loma[4] Spectronic 20 was used at 550 nm for transmittance readings.

Total vitamin B$_6$ was calculated on the wet-weight (ordinarily consumed) basis, moisture- and fat-free basis and nitrogen basis. Percent retention of vitamin B$_6$ was calculated using the following formulas:

(1) Wet-Weight Basis (true retention[5])

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[4] Bausch and Lomb Analytical Systems Division, Rochester, New York.

[5] Murphy, Criner and Gray (1975)

(a) % Retention =
(in meat alone)

$$\% \text{ Retention (in meat alone)} = \frac{ugB_6/g \times \text{total wt. of cooked meat loaf}}{ugB_6/g \times \text{total wt. of raw meat loaf}}$$

,

(b) % Retention =
(including drip)

$$\% \text{ Retention (including drip)} = \frac{(ugB_6/g \times \text{total wt. of cooked meat loaf}) + (ugB_6/g \times \text{total wt. of drip})}{ugB_6/g \times \text{total wt. of raw meat loaf}}$$

(2) Moisture- and Fat-Free Basis (apparent retention[5])

$$\% \text{ Retention} = \frac{ugB_6/g \div [1 - (\%M + \%F)] \text{ of cooked meat loaf}}{ugB_6/g \div [1 - (\%M + \%F)] \text{ of raw meat loaf}}$$

(M: Moisture; F: Fat; moisture and fat times 10^{-2})

(3) Nitrogen Basis

$$\% \text{ Retention} = \frac{ugB_6/g \div \%\text{ N of cooked meat loaf}}{ugB_6/g \div \%\text{ N of raw meat loaf}}$$

Statistical analyses

A randomized complete block design was used to determine whether the difference in the various treatments of the two kinds of meat loaves affected yield, fat, moisture, nitrogen and vitamin B_6 content at any treatment before service. Data from the three replications were subjected to analysis of variance as follows:

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[5]Murphy, Criner and Gary (1975)

Source of Variation	DF
Block (A)	2
Subject (B)	1
A x B	2
Treatment (C)	4
(A x C) + (A x B x C)	16
B x C	4
Error	30
TOTAL	59

In the multiple comparison t-test (Cochran and Cox, 1953; Duncan, 1957), differences among the treatments were considered significant when P was less than or equal to 0.05.

RESULTS

Means and standard deviations for the three replications of all-beef and beef-soy loaves within each treatment are presented in this thesis. All data are shown by types of foodservice system as well as by method of holding, chilling and reheating of baked loaves. For the conventional foodservice system, the loaf analyzed after baking is designated as freshly "baked;" after hot holding at 95°C followed by hot serving at 70°C is designated as "held." For the cook/chill food-service system, the loaf chilled for 24 hours is designated as "chilled;" the loaf reheated in a microwave oven is designated as "MW reheated." The unbaked loaf is designated as "raw."

Heating times and temperatures

Means for heating times and temperatures for the all-beef and beef-soy loaves are given in Tables II and III, respectively. The beef-soy loaves required significantly less (P<0.01) time to reach an internal temperature of 74°C than the all-beef loaves; the all-beef loaves required a mean of 68 minutes, compared with 56 minutes required to bake the beef-soy loaves. Both types of loaves, however, required four minutes to raise the internal temperature to 55°C when reheated in a microwave oven.

The total heating time for the held loaves was 143 minutes for the all-beef loaves, and 132 minutes for the beef-soy ones. These periods of time were significantly longer (P<0.05) than for the reheated products, 71 minutes and 61 minutes for the all-beef and beef-soy loaves, respectively.

Volume and weight of drip and meat loaf

The mean weights of the two kinds of meat loaves after the four treatments, and the weights and volumes of the drip are presented in Table IV (all-beef) and Table V (beef-soy). In the cook/chill food-service system, the weight and volume of the drip were measured right after the initial baking but not after 24 hours of chilling and four minutes of microwave reheating. The total drip volume was divided into lipid and aqueous parts.

For all-beef (Table IV) and beef-soy (Table V), the weights of the held meat loaves were significantly lower (P<0.05) than those of the freshly baked and chilled meat loaves, respectively. The weight of the microwave reheated all-beef loaves, but not beef-soy, were significantly lower than those of the freshly baked loaves (P<0.05). For every heat treatment, the all-beef loaves had a significantly lower weight than the beef-soy ones (P<0.05).

The total drip volumes from freshly baked and held all-beef loaves were 106 ml and 115 ml, with 66 ml and 70 ml in the lipid part, respectively, the remainder being aqueous portion (Table IV). In contrast, the total drip volumes from freshly baked and held beef-soy loaves were 19 ml and 22 ml, with 14 ml and 17 ml in the lipid part, respectively (Table V). The statistical analyses showed that there was no difference in the total drip volume, or in lipid and aqueous parts, for each kind of meat loaf in the different conventional heating treatments. Due to variations among the three replications, the differences in the lipid part between these all-beef and beef-soy loaves were not statistically significant. But in every heating treat-

ment, there was a significantly higher (P<0.05) total drip volume and aqueous part in the all-beef than in the beef-soy loaves (Fig. 3).

The mean weight of drip for the all-beef loaf was 102 gm after freshly baking, and 117 gm after holding; for the beef-soy loaves, the weights were 19 gm and 25 gm, respectively. There was no statistically significant difference in drip weight between freshly baking and holding of each kind of meat loaf. But there was a significantly lower drip weight value (P<0.05) in loaves that had 30% SPC added to them.

Heating losses

Data including total, drip and volatile losses of all-beef and beef-soy loaves, respectively, are also summarized in Tables IV and V. Calculations of percentage of these heating losses were based on weight of the raw loaf (800 gm).

Analysis of variance indicated that significantly lower (P<0.05) total heating losses were found in all four different treatments of 30% soy-substituted loaves (Fig. 4). For both all-beef (Table IV) and beef-soy (Table V) loaves, there were no significant differences in the losses between conventional and cook/chill foodservice systems. The 17% and 5% total heating losses for the freshly baked all-beef and beef-soy loaves, respectively, were similar to the 18% and 6% losses for the all-beef and beef-soy loaves after 24 hours of storage at 3°C. Calculations were made of these heating losses just after the loaves were removed from the oven and refrigerator. Data indicated a 1% loss during chilled storage. In all comparisons, greater total heating losses were observed after holding and microwave reheating. These were significantly greater (P<0.05) for the all-beef loaves than the beef-

soy loaves (Fig. 4). Again, the two foodservice systems had no effect. The 23% and 10% total heating losses for the held all-beef and beef-soy loaves were similar to the 22% and 9% losses for the all-beef and beef-soy loaves baked to 74°C, chilled, and microwave reheated to 55°C. This was surprising since one would expect higher losses for the held loaves that were held a total of 75 minutes, compared with only four minutes for the microwave reheated ones.

Mean drip losses for all-beef and beef-soy loaves right after being baked were 13% and 2%, respectively; for the held loaves, losses were 15% and 3%, respectively. The drip losses of chilled and microwave reheated loaves were calculated based on only one heating treatment. Drip losses from both kinds of meat loaves were approximately the same under different heating treatments. As expected, 30% soy-substitution decreased drip loss significantly ($P<0.05$) in all four heating treatments (Fig. 4). Drip losses consist of fat and water that have melted out during the cooking process, whereas volatile losses are a result of the evaporation of water and other volatile compounds (Paul and Palmer, 1972).

The replacement of 30% of the ground beef with SPC significantly lowered ($P<0.05$) volatile losses (Fig. 4). During holding and microwave reheating of the all-beef (Table IV) and beef-soy (Table V) loaves, volatile losses were increased almost twice, resulting in a highly significant difference ($P<0.01$) compared with those of the freshly baked and chilled ones. Volatile losses, previously found to be directly related to cooking time (Funk and Boyle, 1972), are in agreement with the findings of this study.

Moisture, fat, and nitrogen content

The values for the moisture, fat and nitrogen content for the all-beef and beef-soy loaves of each treatment are presented in Tables VI and VII, respectively.

Among the four treatments, plus unbaked, the all-beef and beef-soy loaves retained the least (P<0.05) percentage of moisture after micro- wave reheating. The percentages of moisture in the 30% soy-substituted microwave reheated loaves (Table VII), but not in the all-beef loaves (Table VI), were significantly lower (P<0.05) than in the raw samples. The mean percentage of moisture for service was lowered, but not sig- nificantly, in the two kinds of held loaves as compared with that of the freshly baked and chilled ones. Among the various treatments, there were no significant differences in moisture content between the all-beef and beef-soy loaves. Except for the raw beef-soy loaves, all of the other treatments of beef-soy loaves were only slightly lower in moisture content than those of the all-beef loaves.

The fat content in the 30% soy-substituted loaves (Table VII) was not affected by treatment. Although heating treatments did not affect the fat content of the all-beef loaves (Table VI), the raw all-beef loaves were significantly higher (P<0.05) levels of fat (19%) than the beef-soy loaves (14%). However, after being baked and submitted to other treatments, the fat contents of the loaves with 0% and 30% SPC were not significantly different, the beef-soy loaves containing slightly less total lipid than the all-beef loaves.

Among the various treatments, the nitrogen content of the raw all-beef loaf was significantly lower (P<0.01) than that of the all-beef

loaves which were either freshly baked, held, chilled or microwave reheated (Table VI). Also, there was a noticeable difference in nitrogen content ($P < 0.05$) between freshly baked and held, freshly baked and reheated, and held and chilled all-beef loaves. In the beef-soy loaves, the only differences were that the raw loaf had significantly lower nitrogen content than the beef-soy loaves which were either freshly baked, held or reheated (Table VII); the other treatments did not have any significant effect on nitrogen content. Analysis of variance indicated significant differences ($P < 0.05$) among nitrogen values of the all-beef and beef-soy loaves in all five treatments. The multiple comparison t-test indicated that the amount of nitrogen in the raw 30% soy-substituted loaf (2.6%) was significantly higher than in the raw all-beef loaf (2.2%).

Vitamin B_6 content

The vitamin B_6 content of the all-beef and beef-soy loaves and their respective drippings are also shown in Tables VI and VII, respectively. The values of the total vitamin B_6 contents of the meat loaves are reported on a wet-weight basis (as consumed), a moisture- and fat-free basis, and a nitrogen basis.

The vitamin B_6 content of beef-soy loaves was similar for all five treatments, including raw, when calculated on a wet-weight basis (Table VII). The various treatments, however, caused significant differences in the all-beef loaves (Table VI). On a wet-weight basis, the freshly baked and reheated all-beef loaves contained more µg vitamin B_6/g ($P < 0.05$) than did the raw all-beef loaf. On the same basis, the held all-beef loaf contained less vitamin B_6 ($P < 0.05$) than

did the microwave reheated one. In all treatments, due to very low

vitamin B_6 content of the SPC, the vitamin B_6 values of the all-beef

loaves were higher (P<0.05) than those of the beef-soy loaves (Fig. 5).

Differences in vitamin B_6 concentration of the all-beef or beef-soy

drip were not significant when calculated on a wet-weight basis.

For the various treatments of the beef-soy loaves, on a moisture-

and fat-free basis of vitamin B_6, no significant differences were

observed (Table VII). However, the raw all-beef samples contained sig-

nificantly more µg vitamin B_6 /g of moisture- and fat-free (P<0.05)

than those that were freshly baked, held, chilled or microwave reheated

(Table VI). The held all-beef loaf had the lowest vitamin B_6 content

on a moisture- and fat-free basis, which was also significantly lower

(P<0.05) than that of the freshly baked all-beef loaf. The average

vitamin B_6 content per gram moisture- and fat-free of the raw all-beef

loaf was 6.13 µg, and that of the raw beef-soy loaf was 4.20 µg

(Tables VI and VII); these findings indicate a marked difference between

them (P<0.01). Besides the big difference between the raw all-beef

and beef-soy, in all other treatments between the two kinds of loaves,

there was a significant difference at the 5% level (Fig. 6).

On a nitrogen basis, the means of vitamin B_6 content of both

kinds of meat loaf are also summarized in Tables VI and VII. In general,

the patterns of vitamin B_6 values expressed on a per gram of nitrogen

basis usually parallel those of the moisture- and fat-free

basis. The significant differences (P<0.05) were due to 30% SPC added

to the loaf in each treatment. The multiple comparison t-test indicated

that the vitamin B_6 content of the raw all-beef loaf (on a nitrogen

basis) was higher (P<0.05) than that of the held, chilled or microwave

reheated all-beef loaves. The held all-beef loaf had significantly lower (P<0.05) vitamin B_6 content than that of the freshly baked and microwave heated all-beef loaves. However, calculated on a nitrogen basis of vitamin B_6, no significant difference was found in the beef-soy loaves among all treatments.

Retention of vitamin B_6

Data on the true and apparent retention of vitamin B_6 in the all-beef and the beef-soy loaves are presented in Tables VIII and IX, respectively. True retention of vitamin B_6 was calculated with and without the drip. The weights of the loaves and drippings (Tables IV and V) were used to calculate percent of true retention of vitamin B_6 in the meat loaves.

True retention in the all-beef loaves ranged from 80.4 to 90.7 percent, and 4.3 to 5.7 percent recovered in the drip. True retention in the beef-soy loaves ranged from 89.3 to 98.4 percent, and transference to the drip was 0.4 to 0.8 percent (Tables VIII and IX). Analysis of variance indicated no significant differences among percentages of vitamin B_6 retained in any treatment of the all-beef and beef-soy loaves and drips (Fig. 7). However, the multiple comparison t-test indicated that the true retention of total vitamin B_6 (meat and drip) in both kinds of loaves after freshly baking (baked) and microwave reheating (reheated) was significantly higher (P<0.05) than after the loaves had been held for 75 minutes (held).

Apparent retention of vitamin B_6, on a moisture- and fat-free basis, was calculated in loaves only and did not include the drip. Analysis of variance indicated that the vitamin B_6 retention in the

all-beef and beef-soy loaves in the cook/chill foodservice system was not different from the conventional foodservice system. Although the retention of vitamin B_6 on a moisture- and fat-free basis of the beef-soy loaves in every treatment was higher than that of the all-beef loaves, no significant differences were found.

Apparent retention of vitamin B_6 in the meat loaves was calculated also on the basis of nitrogen content. The only significant difference was found in the freshly baked all-beef and held all-beef loaves. The former was significantly higher than the latter at the 5% level. The other treatments in either all-beef loaves or beef-soy loaves were not significantly different. The vitamin B_6 retentions were higher in the beef-soy loaves than those in the all-beef loaves, however, the statistical analysis showed no difference between them.

Table II. Average times and temperatures for all-beef loaves[a]
in two simulated foodservice systems

Factor	Conventional		Cook/Chill	
	Baked	Held	Chilled	MW Reheated
Initial baking time (min)	68 ± 0.6	68 ± 3.5	70 ± 2.7	67 ± 3.1
Internal baking temp. (°C)	75 ± 1.6	74 ± 0.0	76 ± 1.6	74 ± 1.0
Chilling time (hr)/temp (°C)	N.A.[b]	N.A.	24/2.8 ± 0.5	24/2.8 ± 0.5
Hot holding time (min)/temp (°C)	N.A.	60/95 ± 3.0	N.A.	N.A.
Hot serving time (min)/temp (°C)	N.A.	15/71 ± 6.1	N.A.	N.A.
Reheating time (min)	N.A.	N.A.	N.A.	4.0 ± 0.0
Internal reheating temp (°C)	N.A.	N.A.	N.A.	55 ± 0.0
Total heating time (min)	68 ± 0.6	143 ± 3.5	70.0 ± 2.7	71 ± 3.1

[a]Means and standard deviations were based on three loaves of each treatment

[b]Not applicable

Table III. Average times and temperatures for beef-soy loaves[a]
in two simulated foodservice systems

Factor	Conventional		Cook/Chill	
	Baked	Held	Chilled	MW Reheated
Initial baking time (min)	56 ± 1.0	57 ± 1.7	58 ± 2.1	57 ± 2.5
Internal baking temp (°C)	74 ± 0	74 ± 0.3	74 ± 0	74 ± 0
Chilling time (hr)/temp (°C)	N.A.[b]	N.A.	24/2.8 ± 0.5	24/2.8 ± 0.5
Hot holding time (min)/temp (°C)	N.A.	60/95 ± 3.0	N.A.	N.A.
Hot holding time (min)/temp (°C)	N.A.	15/70 ± 5.0	N.A.	N.A.
Reheating time (min)	N.A.	N.A.	N.A.	4.0 ± 0.0
Internal reheating temp (°C)	N.A.	N.A.	N.A.	55 ± 0.0
Total heating time (min)	56 ± 1.0	132 ± 1.7	58 ± 2.1	61 ± 2.5

[a]Means and standard deviations were based on three loaves of each treatment

[b]Not applicable

Table IV. Weight and volume (including lipid and aqueous parts) of drip, and weight and heating losses of all-beef loaves[a] in two simulated foodservice systems

Factor	Conventional		Cook/Chill		Statistical Significance[b]
	Baked (B)	Held (H)	Chilled[c](C)	MW Reheated[c](M)	
Weight of loaf (gm)	663.6 ± 24.6	613.2 ± 17.5	656.5 ± 23.1	623.0 ± 15.4	B>C>M>H[d]
Total drip volume (ml)	106.2 ± 27.7	114.7 ± 20.3	104.7 ± 24.5	107.3 ± 20.5	
lipid part (ml)	66.0 ± 19.0	69.7 ± 16.1	63.7 ± 21.9	67.2 ± 19.8	
aqueous part (ml)	40.2 ± 8.4	45.0 ± 5.6	41.0 ± 3.5	40.2 ± 6.4	
Weight of drip (gm)	102.1 ± 27.7	116.9 ± 22.8	104.7 ± 24.7	104.0 ± 17.5	
Drip loss (%)	12.8 ± 3.5	14.6 ± 2.8	13.1 ± 3.1	13.0 ± 2.2	
Volatile loss (%)[e]	4.3 ± 0.4	8.7 ± 0.8	4.9 ± 0.2	9.1 ± 0.3	M>H>C>B[f]
Total heating loss (%)	17.1 ± 3.1	23.4 ± 2.2	17.9 ± 2.9	22.1 ± 1.9	H>M>C>B[d]

[a]Means and standard deviations were based on three loaves of each treatment

[b]Values underscored with the same line are not significantly different

[c]Volume and weight of drip as well as percent drip loss were determined immediately after loaves were baked. Weight of loaves and volatile and total losses were determined after chilling and microwave reheating.

[d]Significant at the 5% level

[e]Volatile loss is the difference between total heating loss and drip loss

[f]Significant at the 1% level

Factor	Conventional		Cook/Chill		Statistical Significance[b]
	Baked (B)	Held (H)	Chilled[c] (C)	MW Reheated[c] (M)	
Weight of loaf (gm)	758.5 ± 5.8	718.8 ± 3.0	752.6 ± 2.6	728.3 ± 1.9	B>C>M>H[d]
Total drip volume (ml)	18.5 ± 3.0	22.3 ± 4.7	17.6 ± 3.5	15.1 ± 3.8	
lipid part (ml)	13.7 ± 3.0	16.7 ± 0.9	14.1 ± 4.9	11.4 ± 4.7	
aqueous part (ml)	4.8 ± 3.9	5.6 ± 4.9	3.4 ± 1.7	3.7 ± 2.4	
Weight of drip (gm)	19.0 ± 1.4	24.6 ± 3.1	17.3 ± 4.8	17.1 ± 1.1	
Drip loss (%)	2.4 ± 0.2	3.1 ± 0.4	2.2 ± 0.6	2.1 ± 0.1	
Volatile loss (%)[e]	2.8 ± 0.6	7.1 ± 0.1	3.8 ± 0.3	6.8 ± 0.1	H>M>C>B[f]
Total heating loss (%)	5.2 ± 0.7	10.2 ± 0.4	5.9 ± 0.3	9.0 ± 0.2	H>M>C>B[d]

[a] Means and standard deviations were based on three loaves of each treatment

[b] Values underscored with the same line are not significantly different

[c] Volume and weight of drip as well as percent drip loss were determined immediately after loaves were baked. Weight of loaves and volatile and total losses were determined after chilling and microwave reheating.

[d] Significant at the 5% level

[e] Volatile loss is the difference between total heating loss and drip loss

[f] Significant at the 1% level

Table VI. Moisture, fat, nitrogen, and vitamin B_6 content of all-beef loaves[a] and drip in two simulated foodservice systems

Factor	Raw (R)	Conventional		Cook/Chill		Statistical Significance[b]
		Baked (B)	Held (H)	Chilled (C)	MW Reheated (M)	
Mosisture content (%)	59.9 ± 1.0	60.7 ± 0.4	59.3 ± 0.5	60.8 ± 0.5	58.3 ± 0.6	C>B>R>H>M[c]
Fat content (%)	19.3 ± 1.0	13.9 ± 0.6	14.0 ± 0.6	13.9 ± 0.8	14.7 ± 1.1	R>M>H>B=C[d]
Nitrogen content (%)	2.22 ± 0.08	2.61 ± 0.08	2.87 ± 0.07	2.66 ± 0.10	2.81 ± 0.06	H>M>C>B>R[e]
Vitamin B_6 in drip (µg/g)		0.42 ± 0.07	0.50 ± 0.06	0.42 ± 0.07[f]	0.42 ± 0.07[f]	
Vitamin B_6 in loaf on wet-weight basis (µg/g)	1.28 ± 0.08	1.40 ± 0.04	1.34 ± 0.05	1.37 ± 0.04	1.47 ± 0.05	M>B>C>H>R[c]
Vitamin B_6 content on moisture- and fat-free basis (µg/g)	6.13 ± 0.24	5.52 ± 0.14	5.02 ± 0.19	5.42 ± 0.18	5.43 ± 0.25	R>B>M>C>H[e]
Vitamin B_6 content on nitrogen basis (µg/g)	57.6 ± 3.1	53.5 ± 2.1	46.8 ± 2.2	51.6 ± 1.2	52.3 ± 2.4	R>B>M>C>H[e]

[a]Means and standard deviations were based on three loaves of each treatment, and duplicate samples in each loaf

Table VI. Continued

[b]Values underscored with the same line are not significantly different

[c]Significant at the 5% level

[d]Significant at the 1% level

[e]Significant at the 5% or less than 1% level

[f]Measured right after removing the loaves from the oven, instead of from the refrigerator or the microwave oven

Table VII. Moisture, fat, nitrogen, and vitamin B_6 content of beef-soy loaves[a] and drip in two simulated foodservice systems

| Factor | Raw (R) | Conventional | | Cook/Chill | | Statistical Significance[b] |
		Baked (B)	Held (H)	Chilled (C)	MW Reheated (M)	
Moisture content (%)	60.9 ± 0.6	60.2 ± 0.4	58.7 ± 0.9	60.3 ± 0.6	58.2 ± 0.7	R>C>B>H>M[c]
Fat content (%)	14.2 ± 0.5	13.1 ± 0.6	13.4 ± 0.5	13.3 ± 0.4	13.5 ± 0.4	
Nitrogen content (%)	2.56 ± 0.08	2.75 ± 0.07	2.78 ± 0.12	2.72 ± 0.08	2.86 ± 0.04	M>H>B>C>R[c]
Vitamin B_6 in drip (μg/g)		0.23 ± 0.15	0.24 ± 0.15	0.23 ± 0.15[d]	0.23 ± 0.15[d]	
Vitamin B_6 in loaf on wet-weight basis (μg/g)	1.05 ± 0.04	1.07 ± 0.06	1.04 ± 0.05	1.05 ± 0.08	1.13 ± 0.08	
Vitamin B_6 content on moisture- and fat-free basis (μg/g)	4.20 ± 0.14	3.99 ± 0.21	3.72 ± 0.13	3.97 ± 0.30	4.0 ± 0.25	
Vitamin B_6 content on nitrogen basis (μg/g)	40.9 ± 1.0	38.8 ± 1.3	37.4 ± 1.0	38.5 ± 2.1	39.6 ± 3.0	

[a]Means and standard deviations were based on three loaves of each treatment, and duplicate samples in each loaf

Table VII. Continued

bValues underscored with the same line are not significantly different

cSignificant at the 5% level

dMeasured right after removing the loaves from the oven, instead of from the refrigerator or the microwave oven

Table VIII. Retention of vitamin B_6 for all-beef loaves[a] in two simulated foodservice systems

Factor	Conventional		Cook/Chill		Statistical Significance[b]
	Baked (B)	Held (H)	Chilled (C)	MW Reheated(M)	
True retention					
% of meat	90.7 ± 3.4	80.4 ± 2.3	87.9 ± 3.6	89.4 ± 1.3	B>M>C>H[c]
% of drip	4.31± 2.48	5.71± 1.25	4.43± 2.46[d]	4.51± 2.44	
% of total (meat & drip)	94.8 ± 5.0	86.1 ± 2.9	‐92.3 ± 4.8	93.9 ± 2.8	B>M>C>H[c]
Apparent retention					
% on moisture- and fat-free basis	90.1 ± 2.7	81.9 ± 3.1	88.5 ± 2.9	88.7 ± 3.9	
% on nitrogen basis	92.0 ± 1.8	80.4 ± 2.5	88.7 ± 2.7	90.0 ± 5.1	B>M>C>H[c]

[a]Means and standard deviation were based on three loaves of each treatment, and duplicate samples in each loaf

[b]Values underscored with the same line are not significantly different

[c]Significant at the 5% level

[d]Measured right after removing the loaves from the oven, instead of from the refrigerator or the microwave oven

Table IX. Retention of vitamin B_6 for beef-soy loaves[a]
in two simulated foodservice systems

Factor	Conventional		Cook/Chill		Statistical Significance[b]
	Baked (B)	Held (H)	Chilled (C)	MW Reheated (M)	
True retention					
% of meat	96.8 ± 2.7	89.3 ± 2.2	94.3 ± 4.7	98.4 ± 4.8	M>B>C>H[c]
% of drip	0.65 ± 0.36	0.77 ± 0.51	0.44 ± 0.25[d]	0.49 ± 0.32[d]	
% of total (meat & drip)	97.4 ± 2.5	90.1 ± 1.9	94.7 ± 4.5	98.9 ± 4.6	M>B>C>H[c]
Apparent retention					
% on moisture- and fat-free basis	95.1 ± 3.6	88.6 ± 2.6	94.6 ± 5.4	95.3 ± 4.8	
% on nitrogen basis	95.1 ± 2.7	91.4 ± 2.3	94.3 ± 2.7	96.8 ± 6.9	

[a]Means and standard deviations were based on three loaves of each treatment, and duplicate samples in each loaf

[b]Values underscored with the same line are not significantly different

[c]Significant at the 5% level

[d]Measured right after removing the loaves from the oven, instead of from the refrigerator or the microwave oven
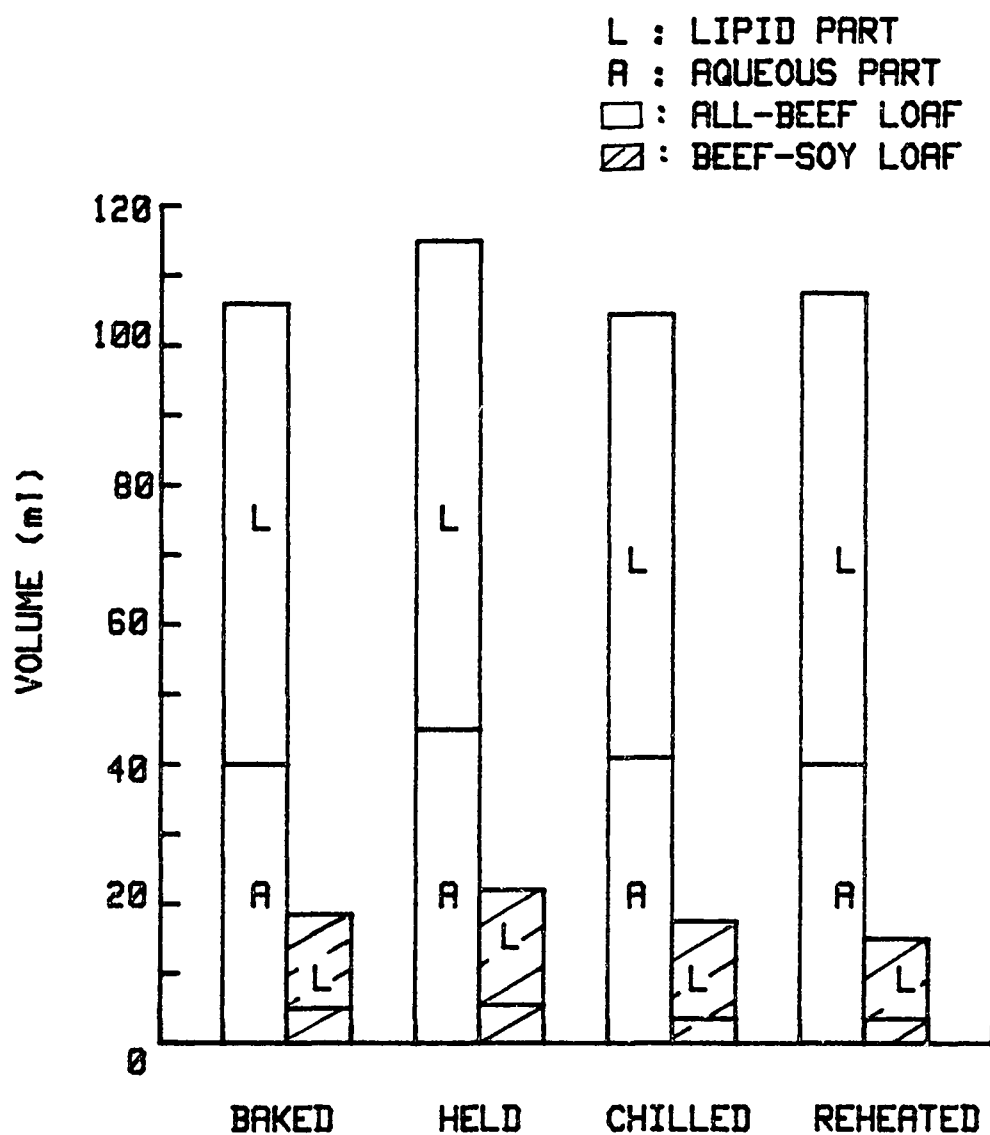
Figure 3. Volume of drippings for all-beef and beef-soy loaves in each treatment.

For all treatments, the volume of drippings from the beef-soy loaves was significantly lower (P<0.05) than that from the all-beef loaves. Aqueous portion of the drip from beef-soy loaves is small (approximately 5%).
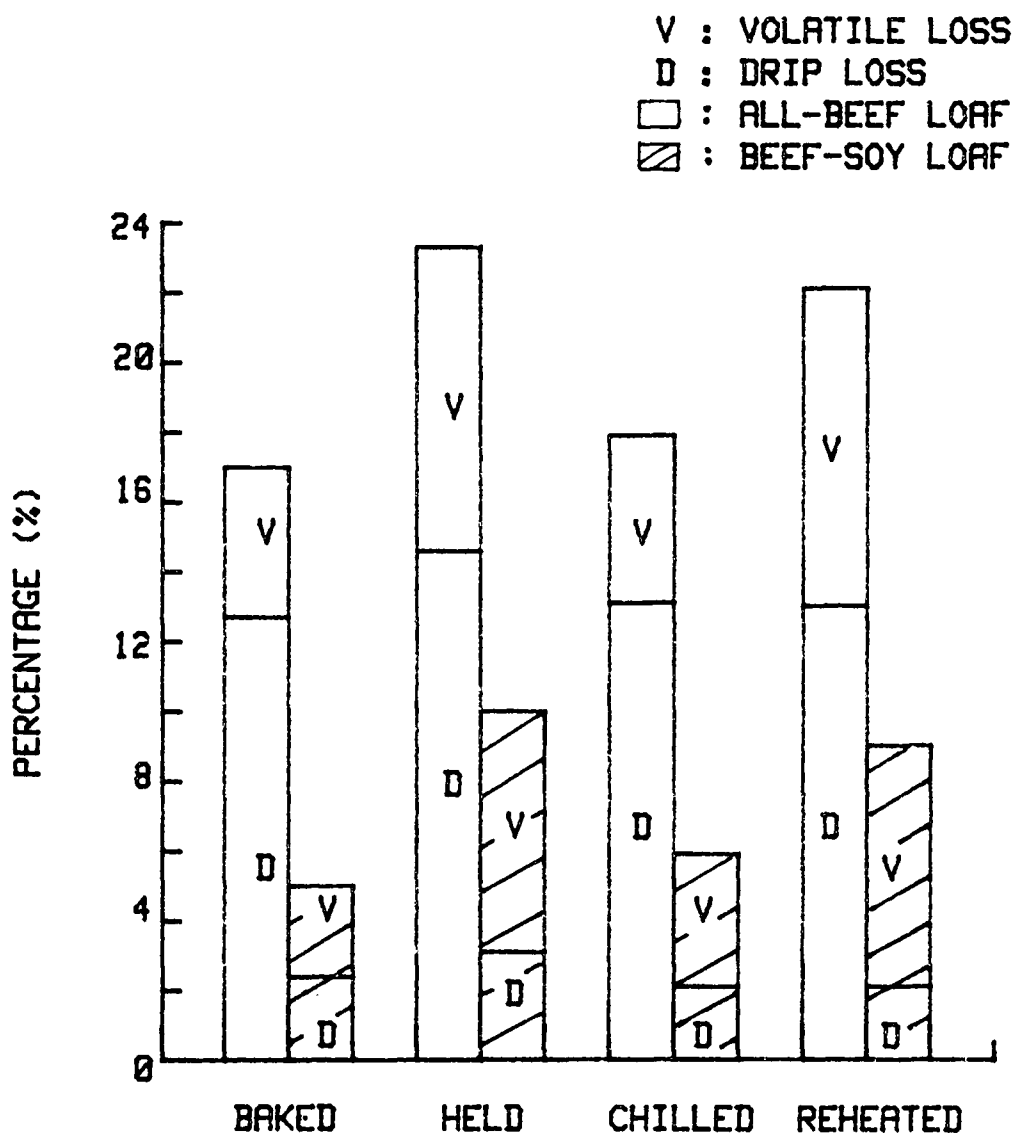
Figure 4. Heating losses of all-beef and beef-soy loaves in each treatment.

For all treatments, the heating losses from the beef-soy loaves was significantly lower (P<0.05) than that from the all-beef loaves.
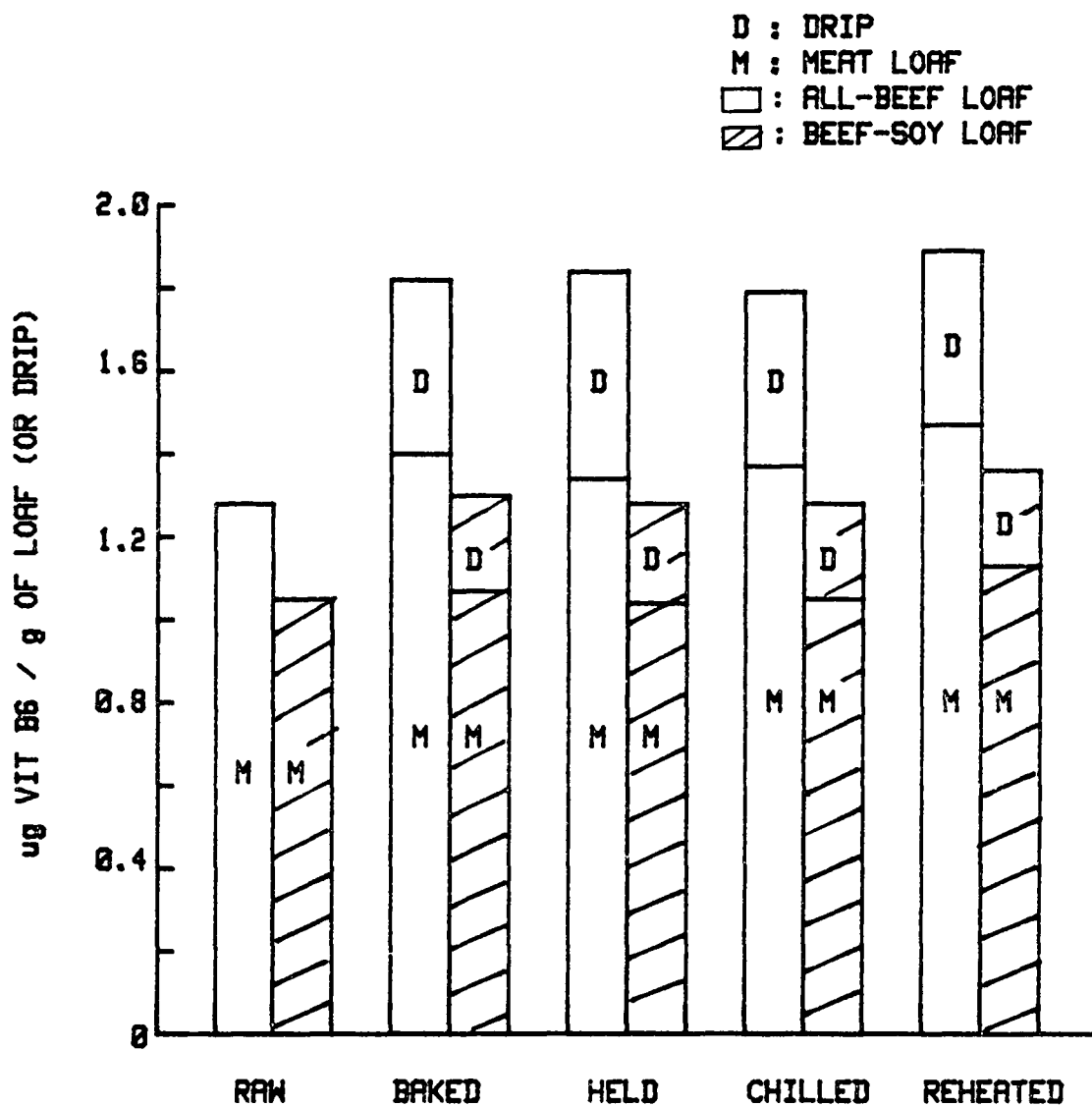
Figure 5. Vitamin B_6 content on wet-weight basis of all-beef and beef-soy loaves in each treatment.

The significant difference (P<0.05) in vitamin B_6 content between the all-beef and beef-soy loaves was due to the low vitamin B_6 content of the SPC used in the beef-soy loaves.
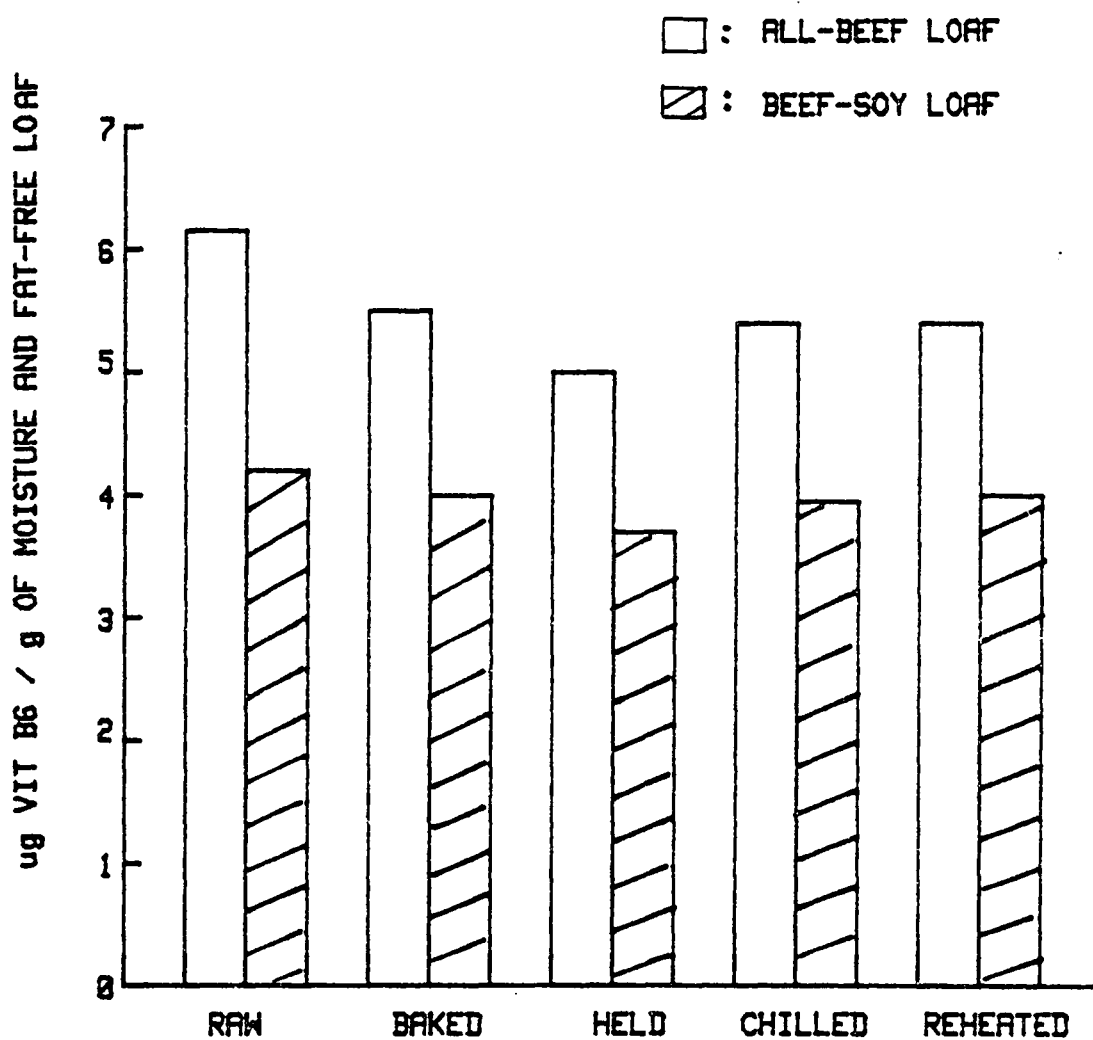
Figure 6. Vitamin B₆ content on moisture- and fat-free basis of all-
beef and beef-soy loaves in each treatment.

Except for the raw loaves, the vitamin B₆ content in all
of other beef-soy loaves was significantly lower (P<0.05)
than that in the all-beef loaves. The difference between
raw all-beef and beef-soy loaves was in the 1% level.

Figure 7. True retention of vitamin B_6 of all-beef and beef-soy loaves in each treatment.

No significant difference was found between all-beef and beef-soy loaves.

DISCUSSION

I. Influence of Treatments on Vitamin B_6
Retention in All-Beef and Beef-Soy Loaves

The meat loaf entrée is commonly served hot. The usual method for handling the hot food in foodservice institutions is to hold it on the steamtable, or to reheat it in a conventional or microwave oven. Some institutions may also use the chilled leftovers of meat loaf t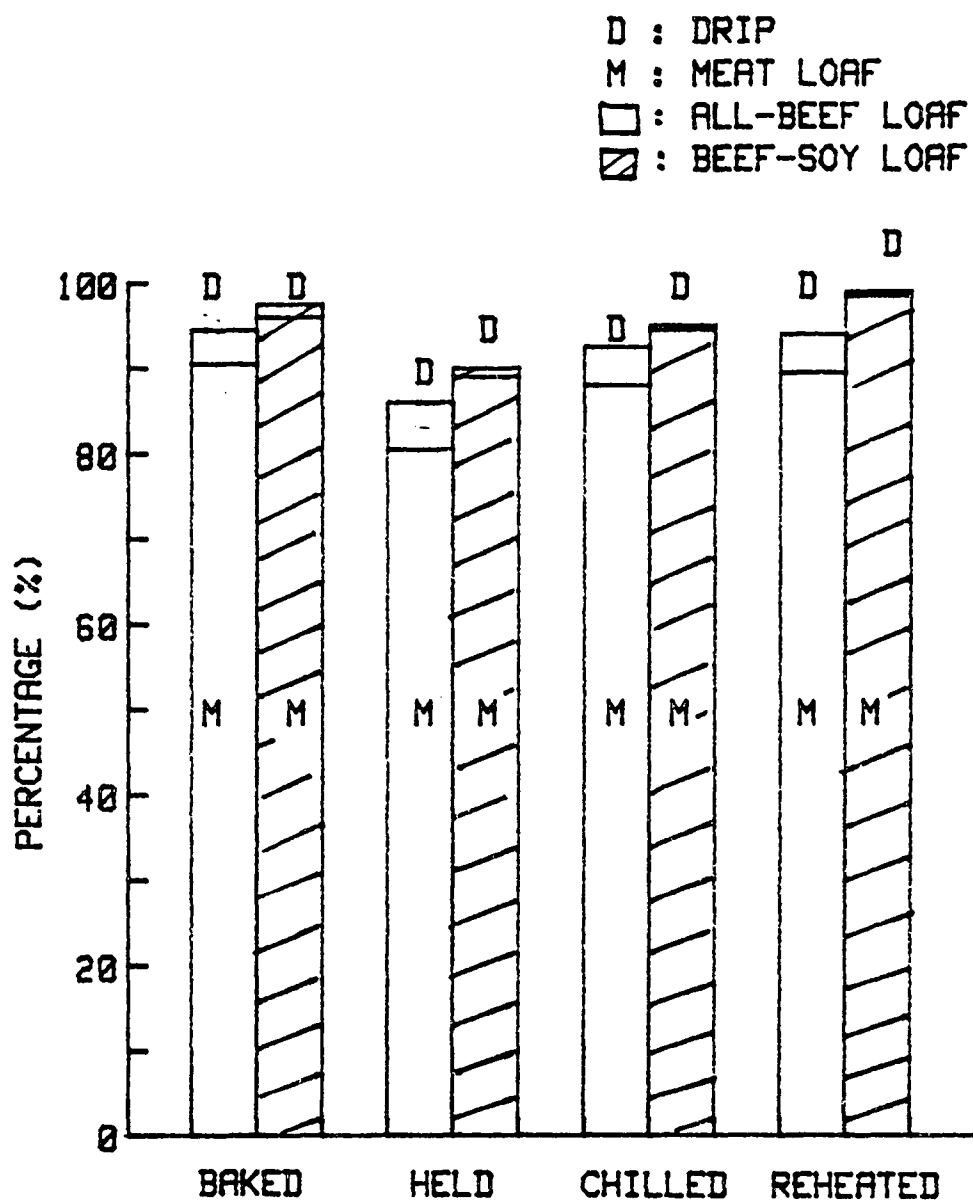o serve in sandwiches. Thus, in this study, the effect on the vitamin B_6 content in different treatments of all-beef and beef-soy loaves was determined. To calculate the vitamin B_6 content of the meat loaves, the raw meat loaf mixture was considered to contain 100% of the vitamin. According to Murphy et al. (1975), apparent retention over-estimated true retention in nearly all instances of cooked food products. Both methods calculating retention were reported without bias in this study.

Since vitamin B_6 is heat labile and water soluble, we hypothesized that holding meat loaves at "hot holding" temperatures and that drip formation will result in lower vitamin B_6 content. In addition to vitamin B_6, we measured drip and volatile losses as well as moisture, fat and nitrogen content in the meat loaves.

Heating losses

At the point of service, after holding (held loaves) and microwave reheating, greater total heating losses were observed in both the all-beef and beef-soy loaves (Tables IV and V) than in the freshly baked and chilled ones. These results are in agreement with those obtained

by Bowers et al. (1974) and Wing and Alexander (1972) who reported more shrinkage and greater cooking losses in poultry held in a warmer or reheated in a microwave oven than in the freshly cooked meat.

During holding and microwave reheating of the all-beef and beef-soy loaves, volatile losses were almost double that of freshly baked and chilled loaves. The longer heating time of the held loaves caused volatile losses from the surface of the two types of the meat loaves. Even though heated for a shorter period of time, reheating by microwave caused similar volatile losses as the held loaves. Usually in conventional cooking, heat is applied to the surface of the food and then conducted unevenly to the inner parts. In contrast, microwaves generate heat throughout the bulk of the food, resulting in an even temperature rise when the food is homogeneous. This may explain the greater volatile losses in the microwave reheated loaves to the loaves of other treatments.

However, there was almost no difference in drip loss and moisture content between the baked and held loaves. Moisture from the waterbath used to hold the loaves may have prevented any further drip and moisture loss of the held loaves. The loaves were covered during the hot holding at 95°C and uncovered during the 70°C one. Despite this moisture contributed by the waterbath, the surface of the held loaves was hard and dried out after holding.

Moisture, fat and nitrogen content

Due to the solubility of vitamin B_6 in water, moisture content or loss was interpreted in this study as a factor indicating potential retention or loss of vitamin B_6 in the meat loaves. Although the heating

loss (drip + volatile) was greater (P<0.05) in the held all-beef
(Table IV) and beef-soy (Table V) loaves, there was no significant
difference in total moisture content between the baked and held
loaves, and between the chilled and held ones (Fig. 4). Of the four
treatments, compared to the raw meat loaf mixture, the microwave
reheated all-beef and beef-soy loaves lost the greatest percentage
of moisture.

Variations in heating processes, handling procedures, and storage
conditions were evidently not sufficient to markedly influence the
fat content of the all-beef (Table VI) and beef-soy (Table VII) loaves
at the point of service. The only difference was that the raw all-beef
loaf had a much higher (P<0.01) percentage of fat content than did the
other all-beef loaves, due to the loss of fat in the drip during baking.
In the beef-soy loaves, percentages of fat content in the raw loaf
mixture were not significantly different from that of the other beef-
soy loaves. SPC, which is low in fat, binds the fat melted out from
the meat during heating, explaining the small difference in fat content
among the various treatments of beef-soy loaves.

The raw all-beef and beef-soy loaves mixtures contained signifi-
cantly less nitrogen than those submitted to the various treatments.
When the temperature rises a little above 60°C, some proteins start to
coagulate and meat starts to shrink. Shrinkage results in some of the
juice in the meat loaf being squeezed out. These heating losses caused
a more concentrated nitrogen content in the cooked loaves. Compared
to the other treatments, the higher nitrogen content in the held and
microwave reheated all-beef and microwave reheated beef-soy loaves

reflected the greater heating losses.

Vitamin B_6 content

The higher moisture and lower nitrogen content of the raw beef-soy loaf mixture explain the lack of differences in the vitamin B_6 content among the different treatments of the beef-soy loaves, when calculated on a wet-weight, moisture- and fat-free, or nitrogen basis. In contrast, the vitamin B_6 content, calculated on each of these bases, of the raw all-beef loaf was significantly higher ($P<0.05$) than that of any other samples of the all-beef loaves. These differences indicate either that vitamin B_6 was transferred to the drip or was unstable during cooking.

The fact that while being held the meat loaves were exposed to heat, light, and oxygen for an extended time, may account for their lower vitamin B_6 content (Tables VI and VII). This loss was higher in the held all-beef loaves than in the beef-soy ones, probably due to the lower vitamin B_6 loss in the drip from the held beef-soy loaf. Under the conditions of this study, it was impossible to determine whether vitamin B_6 loss after holding was due to heat or light destruction, oxidation, or other factors.

Apparently the microwave heat source did not affect the stability of vitamin B_6. Weight losses after microwave reheating were almost entirely volatile losses (Tables IV and V). The presence of vitamin B_6 in the volatile losses of meat has not been reported. Vitamin B_6 per gram of meat loaf was more concentrated after microwave heating, probably because volatile losses did not contain an appreciable amount of vitamin B_6.

Retention of vitamin B_6
_____

Among the various treatments of all-beef loaves, the greatest

mean percent retention of vitamin B_6 is in the freshly baked ones

(Table VIII). But among the various treatments of beef-soy loaves,

the microwave reheated ones retained slightly more vitamin B_6 (Table

IX), probably because of handling procedures, sampling errors, and/or

a lack of sensitivity of the test used.

As expected, the least vitamin B_6 was retained after holding the

all-beef and beef-soy loaves. In a study by Dahl and Matthews (1980),

microwave reheating generally accounted for an additional one-third

loss of thiamin in all-beef loaves. This was not true in our study,

probably because vitamin B_6 is stable when subjected to microwave

reheating.

In calculating true retention of vitamin B_6, the weight and vitamin

B_6 content of the held all-beef and beef-soy loaves was lower than

those of the other treatments (not including raw mixtures), causing

the significantly lower (P<0.05) vitamin B_6 retention of the held

loaves. The microwave reheated all-beef and beef-soy loaves had higher

vitamin B_6 content than the held ones. This would explain the signi-

ficant difference in the true retention of vitamin B_6 between microwave

reheating and holding.

In calculating apparent vitamin B_6 retention in the two types of

loaves, no difference was found on a moisture- and fat-free basis,

probably because two factors (water and fat) were being considered in

the calculation. On nitrogen basis, the only difference was found in

the baked and held all-beef loaves. The reason was that the nitrogen

content of the held loaf was significantly higher than that of the baked one. Other treatments did not indicate any difference.

II. Differences Between All-Beef and Beef-Soy Loaves in Vitamin B_6 Retention

The hypothesis we proposed was that the 30% SPC added to the meat loaf may result in a decreased loss of vitamin B_6. As shown in Tables VIII and IX, the percent true and apparent retention of vitamin B_6 was higher in the beef-soy loaves than in the all-beef loaves. However, these higher values were not statistically significant in either true or apparent retention. Since two of the important functional properties of soy proteins are their ability to bind fat and to retain moisture (Wolf, 1970), it was expected that the incorporation of SPC would result in a decrease in total cooking losses, a subsequent decrease in cooking drip and a possible decrease in volatile losses (Williams and Zabik, 1975). These factors caused the variation in vitamin B_6 retention seen among the different treatments of the two types of loaves in this study.

Heating losses

The addition of soy to the meat loaves decreased drip and volatile losses (Fig. 4). According to Funk and Boyle (1972), volatile losses are directly related to cooking time. In this study, twelve minutes less were required to bake the beef-soy loaves than to bake the all-beef loaves to the same internal temperature. This may be an explanation for the significantly lower volatile losses ($P<0.05$) in the beef-soy loaves.

Drip losses consist of fat and water that has melted out during the cooking process. Since the soy protein binds fat and retains water, less fat and water melted out. This caused significantly smaller drip losses (P<0.05) from the beef-soy loaves than from the all-beef ones (Fig. 4). Consequently, the total heating losses (drip losses + volatile losses) were evidently less (P<0.05) in the beef-soy loaves.

Moisture, fat and nitrogen content

According to Wolf (1970), soy proteins are hydrophilic, and would therefore be expected to absorb and retain water. Nevertheless, except for the raw samples, the moisture content for the 0% and 30% soy-substituted meat loaves (Table VI and VII) were quite similar. This result had also been reported by Williams and Zabik (1975), Shafer and Zabik (1975). The effect of the amount of water used to hydrate the SPC on the final moisture content of the baked beef-soy loaves is not known.

Since the fat content of SPC (A. E. Staley Manufacturing Company) was 0.3%, the addition of 30% SPC to the meat loaf should have had a diluting effect on the fat content of the loaf. Table VII indicates that the fat content of the raw beef-soy mixture was less than in the raw all-beef one. As shown in previous studies, however, the use of SPC has a binding effect on the fat (Williams and Zabik, 1975; Shafer and Zabik, 1975; Nielsen and Carlin, 1974). Therefore, before being baked, the all-beef loaves (Table VI) contained significantly higher levels of fat (P<0.05) than the loaves substituted with 30% SPC (Table VII). However, after being baked more fat was retained in the

beef-soy loaf, resulting in almost the same fat content in both kinds of loaves.

The hydrated SPC contained about 4.6% nitrogen compared to 2.9% nitrogen content in the ground beef (Table I footnote). Thus, the 30% soy-substituted meat loaf had a higher nitrogen content than the 0% soy-substituted one. Before being baked the difference in nitrogen content between the all-beef (Table VI) and the beef-soy loaves (Table VII) was greater ($P<0.05$) than after the loaves had been baked, probably because of more drip and weight loss from the all-beef loaves.

Vitamin B_6 content

The vitamin B_6 content of the raw ground beef was 2.25 µg/g compared to 1.05 µg/g in the SPC (Table I, footnote). Thus, replacing 30% of the meat with hydrated SPC lowered the vitamin B_6 content by approximately 22% in the beef-soy loaves on a wet-weight basis. When calculated on a moisture- and fat-free basis or a nitrogen basis, the differences became greater. Since SPC can partially substitute for meat and since meat is a good source of vitamin B_6, it is suggested that foodservice managers use SPC enriched with pyridoxine, the form of vitamin B_6 which is heat-stable.

As vitamin B_6 is water-soluble, it seems reasonable that some of the vitamin would be recovered in the drip. The drip weight was significantly higher in the all-beef loaves, the vitamin B_6 contained per gram of the drip was almost the same for both the all-beef and beef-soy loaves. Although the total vitamin B_6 content of drip (µg vit. B_6/g x g wt of drip) was greater in the all-beef than the beef-soy, this difference was not statistically significant because of

variation among replications.

Retention of vitamin B_6

The mean true and apparent retention of vitamin B_6 in the all-beef and beef-soy loaves in this investigation were considerably high. The unaccounted for loss of vitamin B_6 in the calculation of true retention suggests that vitamin B_6 is heat-labile.

In true retention, although the vitamin B_6 content was higher in the all-beef loaves, the weight of the cooked all-beef loaf was remarkably lower ($P<0.05$) than that of the cooked beef-soy loaf. These would explain the lack of difference in vitamin B_6 retention between the all-beef and beef-soy loaves when calculated on a wet-weight basis. In apparent retention, higher fat content and lower nitrogen content in the raw all-beef loaf mixture (Table VI) would explain the lack of difference in vitamin B_6 retention between two kinds of meat loaves when calculated on a moisture- and fat-free basis and a nitrogen basis, respectively.

III. The Advantages of Using Beef-Soy Loaves and the Cook/Chill Foodservice System

Two major problems in today's foodservice institutions stand from a shortage of money and energy resources. The cook/chill foodservice system, as described in Chapter Two, saves the employee's working time, and microwave reheating saves energy and more nutritious compared to the conventional holding.

According to this study, the beef-soy loaves required less baking time than did the all-beef loaves, another means of saving energy.

Also, the nitrogen content was higher in the beef-soy loaves than in the all-beef loaves. As nitrogen is an estimate of protein content, evidently the beef-soy loaf contains slightly more protein than the all-beef one for lunches of school children. From the standpoint of economics, the cost of meat is getting higher and higher. If SPC is blended with ground beef, it significantly saves the consumer money. As for yield, because of less shrinkage, the 800 gm (raw) freshly baked beef-soy loaves produced one and a half more servings than did the all-beef loaves (on the basis of 3 oz per serving). In a large quantity foodserivce, this is another important economic factor to consider.

Future work might include: separate the three forms of vitamin B_6 in meat loaf; determine which factor (such as light, heat, or oxygen) affects the loss of vitamin B_6 during holding and reheating; define nutrient loss for other categories of food (such as fast food) submitted to different foodservice systems. The effect of SPC on the retention of vitamin B_6 in beef-soy loaves should be investigated on an actual foodservice unit.

SUMMARY AND CONCLUSION

The present study was undertaken to measure the vitamin B_6 content of meat loaves made with ground beef (all-beef) and in those in which 30% of the beef is replaced by hydrated SPC (beef-soy). In addition to vitamin B_6, moisture, fat, and nitrogen contents were determined in the all-beef and beef-soy loaves that were freshly baked; and in pre-baked loaves that had been held at 95°C for 60 minutes followed by 70°C at 15 minutes; chilled at 2.8°C for 24 hours and microwave reheated for four minutes. Baking time, internal temperature, weight of baked loaves, as well as volume of drip were recorded. These results were obtained:

(1)   for 800 gm of raw meat loaf to reach an internal tempera-
       ture of 74°C in a 177°C oven, 68 minutes were required for
       the all-beef loaves and 56 minutes for the beef-soy ones;

(2)   the weight of the freshly baked all-beef loaves was 664 gm
       and for that of the beef-soy loaves was 759 gm. The
       weight of the drip from the all-beef loaves was 102 gm and
       beef-soy was 19 gm. The weight of held all-beef loaves was
       613 gm and the drip was 117 gm; for the held beef-soy loaves
       it was 719 gm and drip, 25 gm;

(3)   the total drip volume from freshly baked and held all-beef
       loaves was 106 ml and 115 ml; that from the beef-soy loaves
       was 19 ml and 22 ml, respectively;

(4)   the average moisture content ranged from 58 to 61% in the
       all-beef and beef-soy loaves. The means obtained for fat
       content ranged from 14 to 19% in the all-beef loaves and

from 13 to 14% in the beef-soy ones. The average nitrogen
content ranged from 2.2 to 2.9% in the all-beef loaves and
from 2.6 to 2.9% in the beef-soy ones;

(5)   the means obtained for vitamin B_6 ranged from 1.28 to 1.47
μg/g in the all-beef loaves and from 1.04 to 1.13 μg/g in
the beef-soy loaves; from 0.42 to 0.50 μg/g in the all-beef
drippings and from 0.23 to 0.24 μg/g in the beef-soy drippings;

(6)   retention of vitamin B_6 in the all-beef loaves ranged from
80.4 to 90.7% and 4.3 to 5.7% was recovered in the drip.
Retention of vitamin B_6 in the beef-soy loaves ranged from
89.3 to 98.4%, and transference to the drip was 0.4 to 0.8%.
Retention of vitamin B_6 in both all-beef and beef-soy loaves
was better in the cook/chill foodservice system than the
conventional foodservice system. Values for true and
apparent retention of vitamin B_6 were comparable.

Since the SPC used in this research was lower in vitamin B_6
content than the all-beef ones, it is recommended that vitamin B_6-
enriched SPC be used as a meat replacement. The addition of SPC to
beef loaves saved energy, reduced the cost of the meat and yielded
more portions.

REFERENCES

Anonymous, 1980 revised recommended dietary allowances. J. Am.
Diet. Assoc. 75:623, 1979.

Association of Official Analytical Chemists. Official methods of
analysis. 11th ed. p. 791. Washington, D.C.: AOAC 1975.

Bessey, O. A., D. J. Adam, and A. E. Hansen. Intake of vitamin B_6
and infantile convulsions: A first approximation of require-
ments of pyridoxine in infants. Pediatrics 20:33, 1957.

Bobeng, B. J., and B. D. David. HACCP models for quality control of
entrée production in hospital foodservice systems. J. Am. Dietet.
Assoc. 73:530, 1978.

Bowers, J. A., B. A. Fryer and P. P. Engler. Vitamin B_6 in turkey
breast muscle cooked in microwave and conventional ovens.
Poultry Sci. 53:844, 1974a.

Bowers, J. A., B. A. Fryer and P. P. Engler. Vitamin B_6 in pork muscle
cooked in microwave and conventional ovens. J. Food Sci. 39:426,
1974b.

Bowers, J. A., and J. Craig. Components of Vitamin B_6 in turkey breast
muscle. J. Food Sci. 43(5):1619, 1978.

Boyle, M. A., and K. Funk. Thiamin in roast beef held by three methods.
J. Am. Dietet. Assoc. 60:398, 1972.

Bunch, W. L., M. E. Matthews, and E. H. Marth. Hospital chill food-
service systems: acceptability and microbiological characteristics
of beef-soy loaves when processed according to system procedures.
J. Food Sci. 41:1273, 1976.

Bunting, W. R. The stability of pyridoxine added to cereals. Cereal
Chem. 42:569, 1965.

Butz, E. L. World protein markets - a supplier's view. J. Am. Oil
Chemists' Soc. 51:57A, 1974.

Canham, J. E., W. T. Nunes, and E. W. Eberlin. Electroencephalographic
and central nervous system manifestations of B_6 deficiency and
induced B_6 dependency in normal human adults, p. 537. In proc. VI
Intern. Congr. Nutr. E. and S. Linvingston, Ltd., Edinburgh(A).
1964.

Cochran, W. G., and G. M. Cox. Experimental designs. 2nd edition.
New York, Wiley, 1953.

Cort, W. M., B. Borenstein, J. H. Harley, M. Osadca and J. Scheiner. Nutrition stability of fortified cereal products. Food Technol. 30(4):52, 1976.

Coursin, D. B. Convulsive seizures in infants with pyridoxine-deficient diets. J. Amer. Med. Assoc. 154:406, 1954.

Dahl, C. A., and M. E. Matthews. Hospital cook/chill foodservice systems. J. Am. Dietet. Assoc. 75:34, 1979.

Dahl, C. A. and M. E. Matthews. Cook/chill foodservice system with a microwave oven: thiamin content in portions of beef loaf after microwave-heating. J. Food Sci. 45:608, 1980.

Daoud, H. N., B. S. Luh and M. W. Miller. Effect of blanching, EDTA and $NaHSO_3$ on color and vitamin B_6 retention in canned garbanzo beans. J. Food Sci. 42:375, 1977.

Davis, M. K., M. E. Gregory and K. M. Henry. The effect of heat on the vitamin B_6 of milk. II. A comparison of biological and micro-biological tests of evaporated milk. J. Dairy Res. 26:215, 1959.

Day, E. J., H. D. Alexander, H. E. Sauberlich and W. D. Salmon. Effects of gamma radiation on certain water-soluble vitamins in raw ground beef. J. Nutr. 62:27, 1957.

DeRitter, E. Stability characteristics of vitamins in processed foods. Food Technol. 30(1):48, 1976.

Dickerson, R. W., and R. B. Read. Cooling rates of food. J. Milk Food Technol. 36:167, 1973.

Donald, E. A., L. D. McBean, M. H. W. Simpson, M. F. Sun and H. E. Aly. Vitamin B_6 requirement of young adult women. Am. J. Clin. Nutr. 24:1028, 1971.

Driskell, J. A., J. M. Geders and M. C. Urban. Vitamin B_6 status of young men, women, and women using oral contraceptives. J. Lab. Clin. Med. 87:813, 1976.

Duncan, D. B. Multiple range test for correlated and heteroscedastic means. Biometrics 13:164, 1957.

Engler, P. P., and J. A. Bowers. Vitamin B_6 content of turkey cooked from frozen, partially frozen and thawed states. J. Food Sci. 40:615, 1975a.

Engler, P. P., and J. A. Bowers. Vitamin B_6 in reheated, held, and freshly cooked turkey breast. J. Am. Dietet. Assoc. 67:42, 1975b.

Erickson, S. E., and R. E. Boyden. Thiamine and riboflavin content of turkey cooked by institutional methods. Ky. Agric. Exper. Station Bull. No. 504, 1947.

Eshbach, C. E. Foodservice management. CBI Publishing Company, Inc. Boston, 1979.

Food & Nutr. Serv.: Textured vegetable protein products (B-1) to be used in combination with meat for use in lunches and suppers served under chilled feeding programs. FNS Notices 219, USDA, Feb. 22, 1971.

Funk, K., and M. A. Boyle. Beef cooking rates and losses. J. Am. Dietet. Assoc. 61:404, 1972.

Glew, G. Cook/Freeze catering. Faber and Faber, London, 1973.

Goodhart, R. S., and M. E. Shils. Modern nutrition in health and disease. Lea and Febiger, Philadelphia, 1980.

Grabow, J. D., and H. Linkswiler. Electroencephalographic and nerve-conduction studies in experimental vitamin B_6 deficiency in adults. Am. J. Clin. Nutr. 22(11):1429, 1969.

Greenberg, L. D., D. Bohr, H. McGrath and J. F. Rinehart. Xanthurenic acid exceretion in the human subject on a pyridoxine-deficient diet. Arch. Biochem. 21:237, 1949.

Gregory, J. F., and J. R. Kirk. Interaction of pyridoxal and pyridoxal phosphate with peptides in a model food system during thermal processing. J. Food Soc. 42(6):1554, 1977.

Gregory, J. F., and J. R. Kirk. Assessment of roasting effect on vitamin B_6 stability and bioavailability in dehydrated food systems. J. Food Sci. 43:1585, 1978.

Gregory, III, J. F., and J. K. Kirk. The bioavailability of vitamin B_6 in foods. Nutr. Rev. 39(1):1, 1981.

Gyorgy, P. Developments leading to the metabolic role of vitamin B_6. Am. J. Clin. Nutr. 24:1250, 1971.

Harris, R. S., and H. Von Loesecke. Nutritional evaluation of food processing. John Wiley and Sons, Inc., New York. 1975.

Hassinen, J. B., G. T. Durbin, and F. W. Bernhart. The vitamin B_6 content of milk products. J. Nutr. 53:242, 1954.

Hawkins, W. W., and J. Barsby. An experiment on human vitamin B_6 deprivation. Science 108:284, 1948.

Head, M. K., R. J. Weeks, and E. Gibbs. Major nutrition in the Type A lunch. 1. Analyzed and calculated values of meals served. J. Am. Dietet. Assoc. 63:620, 1973.

Henderson, L. M., H. A. Waisman and C. A. Elvehjem. The distribution
of pyridoxine (vitamin B_6) in meat and meat products. J. Nutr.
21:589, 1941.

Hodson, A. Z. Vitamin B_6 in sterilized milk and other milk products.
J. Agric. Food Chem. 4:876, 1956.

Holmes, Z. A., L. Miller, M. Edwards, and E. Benson. Vitamin retention
during home drying of vegetables and fruits. Home Econ. Res. J. 7:
258, 1979.

Judge, M. D., C. G. Haugh, G. L. Zachariah, C. E. Parmelee, and R. L.
Pyle. Soya additives in beef patties. J. Food Sci. 39:137, 1974.

Kahrl, W. L. Planning and operating a successful food service opera-
tion. An affiliate of Lebhar-Friedman, Inc., New York, 1973.

Kaud, F. A. Implementing the chilled food concept. Hospitals, J.A.H.A.
46(15):97, 1972.

Keskinel, A., J. C. Ayers, and H. E. Snyder. Determination of oxidative
changes in raw meats by 2-thiobarbituric acid method. Food
Technol. 18:101(Feb.), 1964.

Kirksey, A., K. Keaton, R. P. Abernathy and J. L. Greger. Vitamin B_6
nutritional status of a group of female adolescents. Am. J. Clin.
Nutr. 31:946, 1978.

Koncel, J. A. Planning pervades conversion to cook/chill system.
Hospitals, J.A.H.A. 50(22):87, 1976.

Kylen, A. M., B. H. Mcgrath, E. L. Hallmark, and F. O. Van Duyne.
Microwave and conventional cooking of meat. J. Am. Dietet. Assoc.
45:139, 1964.

Lachance, P. A., A. S. Ranadive, and J. Matas. Effects of reheating
convenience foods. Food Technol. 27(1):36, 1973.

Livingston, G. E. Design of a food service system. Food Technol.
22:35(Jan.), 1968.

Livingston, G. E. Preprepared food: make or buy? - Part I. Hospitals,
J.A.H.A. 46(17):135, 1972.

Lushbough, C. H., J. M. Weichman, and B. S. Schweigert. The retention
of vitamin B_6 in meat during cooking. J. Nutr. 67:451, 1959.

McGuckian, C. A. T. The A.G.S. food system - chilled pasteurized food.
Cornell Hotel Rest. Admin. Q. 10:87(May), 1969.

McIntire, J. M., B. S. Schweigert, and C. A. Elvehjem. The choline and
pyridoxine content of meats. J. Nutr. 28:219, 1944.

Meyer, B. H., M. A. Mysinger and L. A. Wodarsky. Pantothenic acid and vitamin B_6 in beef. J. Am. Dietet. Assoc. 54:122, 1969.

Miller, L. T., and M. Edwards. Microbiological assay of vitamin B_6 in blood and urine. "Methods in vitamin B_6 nutrition analysis and status assessment." Edited by Leklem, J. E., and R. D. Reynolds, Plenum Press, New York and London, 1981.

Miller, L. T., M. J. Dow and S. C. Kokkeler. Methionine metabolism and vitamin B_6 status in women using oral contraceptives. Am. J. Clin. Nutr. 31:619, 1978.

Molony, C. J., and A. H. Parmelee. Convulsions in young infants as a result of pyridoxine (vitamin B_6) deficiency. J. Amer. Med. Assoc. 154:405, 1954.

Munsell, H. E., F. Streightoff, B. Bendor, M. L. Orr, S. R. Ezekiel, M. H. Leonard, M. E. Richardson, and F. G. Koch. Effect of large-scale methods of preparation on the vitamin content of food. 3. Cabbage. J. Am. Dietet. Assoc. 25:420, 1949.

Murphy, E. W., P. C. Koons and L. Page. Vitamin content of Type A school lunches. J. Am. Diet. Assoc. 55:372, 1969.

Murphy, E. W., Criner, P. E., and Gray, B. C. Comparisons of methods for calculatin retentions of nutrients in cooked foods. J. Agric. Food Chem. 23(6):1153, 1975.

Nagel, A. H., and R. S. Harris. Effect of restaurant cooking and service on vitamin content of foods. J. Am. Dietet. Assoc. 19:23, 1943.

National Academy of Sciences. "Recommended Dietary Allowances." 9th ed., N.A.S., Washington, D. C. 1980.

Nielson, L. M., and A. F. Carlin. Frozen, precooked beef and beef-soy loaves. J. Am. Dietet. Assoc. 65:35, 1974.

Orr, M. L. Pantothenic acid, vitamin B_6, and vitamin B_{12} in foods. Home Econ. Res. Rept. 36, USDA, Washington, D.C., 1969.

Passmore, R., B. M. Nicol, M. N. Rao, G. H. Beaton, and E. M. DeMayer. Handbook on human nutritional requirements. Rome: Food and Agriculture Organization of the United Nations, 1974.

Paul, P. C., and H. H. Palmer. Food theory and applications. John Wiley and Sons, Inc., New York, New York, 1972.

Phillips, D. F. The meat shortage reviewed. Hospitals, J.A.H.A. 47 (22):57, 1973.

Polansky, M. M. Vitamin B_6 components in fresh and dried vegetables. J. Am. Dietet. Assoc. 54:118, 1969.

Polansky, M. M., and E. W. Murphy. Vitamin B_6 components in fruits and nuts. J. Am. Dietet. Assoc. 48:109, 1966.

Polansky, M. M., and E. W. Toepfer. Vitamin B_6 components in some meats, fish, dairy products, and commerical infant formulas. J. Agr. Food Chem. 17:1394, 1969.

Raab, C. A., B. S. Luh, and B. S. Schweigert. Effect of heat processing on the retention of vitamin B_6 in lima beans. J. Food Sci. 38:544, 1973.

Rakosky, J. Jr. Soy products for the meat industry. J. Agr. Food Chem. 18(6):1005, 1970.

Rakosky, J. Jr. Soy Grits, flour, concentrates and isolates in meat products. J. Am. Oil Chemists' Soc. 51:123A, 1974.

Richardson, L. R., S. Wilkes and S. J. Ritchey. Comparative vitamin B_6 activity of frozen and heat-processed foods. J. Nutr. 73:363, 1961.

Rinke, C. W. J. Three major systems reviewed and evaluated. Hospitals, J.A.H.A. 50(4):73, 1976.

Sato, K., and G. R. Hegarty. Warmed over flavor in cooked meats. J. Food Sci. 36:1098, 1971.

Sauberlich, H. E., and J. E. Canham. Vitamin B_6. Modern nutrition in health and disease (5th ed.). Goodhart and Shils, Philadelphia: Lea and Felbiger, p. 210, 1973.

Scales, F. M., and Harrison, A. P. Boric acid modification of the Kjeldahl method for crop and soil analysis. J. Ind. and Eng. Chem. 12:350, 1929.

Schroeder, H. A. Losses of vitamins and trace minerals resulting from processing and preservation of foods. Am. J. Clin. Nutr. 24:562, 1971.

Sebrell, W. H., and R. S. Harris. The vitamins: chemistry, physiology, pathology, assay, Vol. II (2nd ed.). New York: Academic Press, 1968.

Shafer, M. A. M., and M. E. Zabik. Dieldrin, fat and moisture loss during the cooking of beef loaves containing texturized soy protein. J. Food Sci. 40:1068, 1975.

Snyderman, S. E., L. E. Holt, Jr., R. Carretero, and K. G. Jacobs. Pyridoxine deficiency in the human infant. Amer. J. Clin. Nutr. 1:200, 1953.

Southgate, D. A. T. A procedure for the measurement of fats in foods. J. Sci. Fd. Agri. 22:591, 1971.

Storvick, C. A., and J. M. Peters. Methods for the determination of vitamin B_6 in biological materials. Vitamins Hormones 22:833, 1964.

Thormer, M. E., and P. B. Manning. Quality control in food service. The AVI Publishing Company, Inc., 1976.

Toepfer, E. W., M. M. Polansky, L. R. Richardson, and S. Wilkes. Comparison of vitamin B_6 values of selected food samples by bioassay and microbiological assay. J. Agric. Food Chem. 11:523, 1963.

Toepfer, E. W., and M. M. Polansky. Microbiological assay of vitamin B_6 and its components. J. Assoc. Anal. Chem. 53:546, 1970.

Tower, D. B. Nutrition Symposium Series No. 12. National Vitamin Foundation, New York, New York. 1956.

Vilter, R. W., J. F. Mueller, H. S. Glazer, T. Jarrold, J. Abraham, C. Thompson, and V. R. Hawkins. The effect of vitamin B_6 deficiency induced by desoxypyriodoxine in human beings. J. Lab. Clin. Med., 42:335, 1953.

Westerman, D. B. The kitchen reporter. Kelvinator Kitchen, Detroit, 1948.

Williams, C. W., and M. E. Zabik. Quality characteristics of soy-substituted ground beef, pork and turkey meat loaves. J. Food Sci. 40:502, 1975.

Wing, R. W., and J. C. Alexander. Effect of microwave heating on vitamin B_6 retention in chicken. J. Am. Dietet. Assoc. 61:661, 1972.

Wolf, W. J. Soybean proteins: their functional, chemical and physical properties. J. Agr. Food Chem. 18:969, 1970.

Wolford, K. M. Beef/soy: Consumer acceptance. J. Am. Oil Chemists' Soc. 51:131A, 1974.

Wood, M. A., A. R. Collings, V. Stodola, A. M. Burgoin, and F. Fenton. Effect of large-scale food preparation on vitamin retention: cabbage. J. Am. Dietet. Assoc. 22:677, 1946.

Woodring, M. J., and C. A. Storvick. Vitamin B_6 in milk: Review of literature. J. Assoc. Off. Anal. Chem. 43:63, 1960.

Zallen, E. M., M. J. Hitchcock, and G. E. Goertz. Chilled food systems. J. Am. Dietet. Assoc. 67:552, 1975.