A Cross-cultural Study of Taste Thresholds and Hedonic Response in Selected Canadian and Peruvian Populations

by

Barbara Ann Macdonald

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BARBARA ANN MacDONALD

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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ABSTRACT

The comparability of gustatory response in Canadian and Peruvian university staff and students was evaluated. Measurements included determination of detection thresholds for the primary tastes in aqueous solution and potato puree. Thresholds were determined using ASTM method E679-79, a forced choice ascending method of limits. In aqueous solution, Peruvians and Canadians were found to possess similar sensitivities for quinine sulphate and sodium chloride but Canadian thresholds for glucose and citric acid were significantly lower than those of the Peruvians. Respective Peruvian and Canadian thresholds for the primary tastes were as follows, quinine sulphate = 0.0010 mM and .0013 mM, sodium chloride = 1.8255 mM and 1.3143 mM, glucose = 21.6684 mM and 14.0265 mM, citric acid = 0.0705 mM and 0.0423 mM. The higher sourness threshold for the Peruvians could be related to their higher frequency of ingesting lemons and lemonade.

Bitter and salty thresholds determined in potato puree were higher than those in aqueous solution for both Canadians and Peruvians. Bitter thresholds, were still remarkably low; quinine sulphate was detectable at a concentration of 5 to 9 ppm in potato compared to approximately 0.80 ppm in aqueous solution. Threshold means for sodium chloride were 217 ppm (Peruvians) and 224 ppm (Canadians) in potato and 108 ppm (Peruvians) and 72.97 ppm (Canadians) in water. Salt detection thresholds for females in both cultural groups were

lower than those for males. Masking effects of the puree on thresholds did not differ among the cultural groups or among males and females. Peruvians and Canadians showed similar trends in hedonic response to bitter and salty tastants in potato puree. Both groups preferred increasing concentrations of sodium chloride (highest concentration tested = 2343 ppm) and decreasing concentrations of quinine sulphate (lowest concentration tested = 9 ppm). Threshold sensitivity was not associated with hedonic response.

Similar Canadian and Peruvian thresholds for quinine sulphate and sodium chloride in aqueous solution and potato puree indicate that Canadian panels could be used to detect bitterness in Andean potato products.

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CHAPTER 1

INTRODUCTION

The Andean Highlands of Peru have traditionally formed a resource-limited region, prone to poverty. Due to less than ideal soil and meteorological conditions, agriculture is limited to a few specialized Andean crops including potatoes, quinoa and faba beans. These foods possess potential as excellent sources of nutrition and researchers at Peruvian provincial universities have been attempting to improve the quality and yields of the processed crops. Improved marketability of these crops will allow Highlanders to generate much needed income to diversify their diet and buy other necessities not produced within their communities.

One of the most promising crops in this respect is the bitter potato and its processed product 'chuno blanco'. Bitter potatoes are grown extensively throughout the highest zones of the Andes and form a staple of the diet providing a significant source of protein and calories to 9,000,000 people living at elevations of 2,500 to 4,000 m (King and Gershoff, 1987). They are consumed at a level of 0.5 kg/day/person or more and during any given meal may occupy the entire plate (Woolfe, 1987).

Bitter potatoes are so named due to their bitter flavour believed to be imparted by the presence of glycoalkaloids. In addition to producing this unacceptable taste, glycoalkaloids are toxic and consequently, the potatoes must be processed to remove this bitter component prior to consumption. Traditional processing mainly consists of a leaching step to remove glycoalkaloids and a freeze-drying step for preservation. The resulting product, chuno blanco, resembles the original potato but has a white, chalky appearance, a dense texture and a bland flavour. Chuno can be kept for 5 to 7 years, an important property in a region prone to variations in yields resulting from frost, storms and drought (Werge, 1978). Chuno may be consumed in soups and stews, steam-heated with cheese, or as a dessert called mazamorra when mixed with fruit and molasses (Werge, 1978).

Traditional processing is effective in terms of preservation and results in a reduction of glycoalkaloid levels in bitter potatoes from an average of greater than 30 mg/100g to approximately 5mg/100g fresh weight (Werge, 1978). The process however, is unhygienic, labour and time intensive, and may produce arthritis in producers. Furthermore, it requires a great deal of open space, a heavy frost (i.e. is dependent on climate) and a source of cold running water (Werge, 1978). One of the aims of the International Development Research Centre's project on Andean crops is to study the chuno-making process and develop technology appropriate to the region. Expected benefits would include reduced labour and time inputs plus a more acceptable final product for home consumption and sale.

The techniques employed in sensory analysis can be used to ensure that new processing techniques result in products equal in consumer acceptability to those produced by traditional methods. The present study was designed to produce preliminary information in this respect. The purpose of the study was to examine taste sensitivity and hedonic response in Peruvians and Canadians and to measure masking effects on sensitivity resulting from interactions with potato taste and texture. The cross-cultural comparison was necessary so that the possible future use of Canadian panelists in the assessment of foods for the Peruvian market could be justified. The resulting information will aid in the development of methods for assessing consumer acceptability of Andean crops.

The specific objectives of the study were:

1) To determine and compare detection threshold values for salt, sweet, bitter and sour tastants in selected Canadian and Peruvian populations.
2) To examine the relationship between detection thresholds and diet history.
3) To measure and compare masking effects of a commercial potato puree on taste thresholds for salt and bitter tastants in these same populations.
4) To examine the relationship between taste thresholds and hedonic ratings for salt and bitter tastants in a commercial potato puree.

CHAPTER 2

REVIEW OF LITERATURE

TASTE THEORY

Taste Physiology

Taste receptors are located in the taste buds found throughout the oral cavity on the tongue, soft palate, epiglottis and the larynx. The taste buds are found in three different types of papillae on the tongue: the circumvallate, which form a V-line toward the back of the tongue, the fungiform toward the front of the tongue and the foliate along the sides of the tongue (Guyton, 1976). The buds possess a pumpkin-like structure and are composed of about 40 modified epithelial cells whose tips end in microvilli. These small hairs protrude from a taste pore which provides contact with the cavity of the mouth (Guyton, 1976). Located among the taste cells is a network of taste nerve fibers that are stimulated by the cells. It is believed that chemical substances bind weakly to sites on the taste cells resulting in the release of a transmitter to the axon endings (Oakley, 1986). Taste impulses are believed to pass through the 5th (lingual), 7th (facial), 9th (glossopharyngeal) and 10th (vagus) cranial nerves with synapsis at the tractus solitarius (Guyton, 1976). Second order neurons then pass the message to the thalamus, where third order neurons ultimately transmit to the cerebral cortex (Guyton, 1976).

Taste Quality Perception

It is believed that there are four primary tastes which in various combinations give rise to the spectrum of tastes that humans perceive. These tastes are sweet, salty, sour and bitter. The sensation of sweetness is produced by a variety of non-ionized aliphatic hydroxy compounds, particularly alcohols, glycols, sugars and sugar derivatives; of saltiness by sodium chloride; of sourness by organic acids such as citric and tartaric; and of bitterness by alkaloids such as quinine, caffeine and strychnine (Amerine et al., 1965). The bitter taste is often associated with toxins, such as glycoalkaloids, in plants. The human tendency to reject this taste in high intensity probably serves a protective function (Guyton, 1976).

It has been determined that most taste buds do not display specificity, but rather respond to varying extents to most of the primary tastes (Guyton, 1976). It has been proposed that in order to give rise to the four taste sensations, specific nerve fiber types may exist whose activities parallel the four primary taste qualities (Oakley, 1986).

Taste Thresholds

Individual sensitivity to the basic tastes is commonly evaluated by threshold determinations. The detection threshold, which is the minimum detectable concentration of a substance, and the recognition threshold, which is the concentration at which a specific taste can be recognized, are the types of thresholds commonly reported (Amerine et al., 1965). The concentration of the recognition threshold is higher than that of the detection threshold (Amerine et al., 1965).

There is a great deal of variability reported for human subjects for the four basic taste thresholds. As an example, Guadagni et al. (1973) found that thresholds for limonin in water ranged from 0.075 mg/l (most sensitive) to 5 mg/l (least sensitive) reflecting a ratio of 67. A certain degree of individual variation in taste ability is to be expected and may simply be a function of normal genetic variation in receptor mechanisms (Oakley, 1986). The majority of the variation in the literature however, is probably due to procedural differences including variations in technique, stimulus and medium chemicals, number of trials, degree of procedural instruction, statistical analysis, physical conditions (e.g. temperature), area stimulated, age, sex, experience of panelists (Kelty and Mayer, 1971). A certain degree of intra-subject variability can also be expected due to such factors as differing levels of background activity in the sensory system and changes in motivation (Engen, 1986).

FACTORS AFFECTING TASTE FUNCTION

The factors affecting taste sensitivity and preferences are not well understood. It is believed that both genetics and experience play a role in the genesis of gustatory function. What is unclear is the contribution of each of these elements to taste response.

Cross-cultural Studies of Taste Response

An interesting way of further studying the factors affecting taste function is to compare the taste sensitivities and preferences of different populations in cross-cultural studies. While there is not a wealth of information on this topic, it has been shown that there is consistency in the thresholds and preferences of western populations. Sweetness is perceived to be pleasant, saltiness is pleasant at low levels but unpleasant as concentration increases, and sourness and bitterness are generally unpleasant (Moskowitz et al., 1975). Preferences and sensitivities to the four tastes, however, have been shown to differ among cultures. Whether these differences are genetically or environmentally controlled is not known (Johns and Keen, 1985). Some authors hold the view that taste sensitivity may act as an adaptation of man to his environment. Increased or decreased sensitivity may confer a selective advantage to individuals who live in resource-limited environments. As an example, Greene (1974) tested the hypothesis that taste sensitivity to phenylthiocarbamide (PTC) would reflect an individual's sensitivity to, and thus his ability to reject, naturally occurring antithyroid compounds. It was determined in a comparison of two Andean communities, that PTC taste sensitivity was correlated with visual-motor perception. The author claimed that this association may have been due to the more sensitive tasters of PTC limiting their intake of bitter tasting goitrogens, thereby improving the probability of normal neurological maturation. Frisancho et al. (1977) also determined that Peruvian highland Quechua Indians had a much lower frequency of PTC non-tasters than lowland Quechuas and Mestizos (3% vs. 6.8%). As further support for the "selective advantage" theory, Davis (1978), in a comparison of 120 Yucatan inhabitants and 83 U.S. citizens, determined that incidence of PTC non-tasting was higher in the Mexicans than the Americans. It was hypothesized that PTC non-tasters would perceive caffeine as less bitter and would therefore more readily accept coffee. Coffee is an important source of niacin in this area which has a high incidence of pellagra.

Cultural studies comparing the ability of individuals to taste all four basic tastes are scant. Moskowitz et al. (1975) compared Indian medical students to illiterate Indian labourers and found that the medical students (an urban population) had taste preferences very similar to those of western populations. The labourers, on the other hand, who subsisted on a sparse diet containing many sour foods (e.g.

tamarind fruit) reported that citric acid (sour) became increasingly pleasant as concentration increased and that quinine sulphate (bitter) was exceptionally pleasant at low concentrations and became less pleasant only with large increments in concentration. Differences in sensitivity between the two groups were not found. The authors postulated that dietary experience could be a partial explanation for the anomalous pleasantness ratings for sourness and bitterness.

Bertino et al. (1983) in a more recent study examined intensity and pleasantness scores for sucrose, sodium chloride and caffeine in 34 American and 28 resident Taiwanese students. It was determined that the subjects of Taiwanese descent rated sucrose in aqueous solution as tasting sweeter, and more pleasant, than the American subjects. Salt was also found to be more pleasant by the Taiwanese and caffeine was rated as being more bitter, although this trend did not reach statistical significance. Sucrose ratings were also made in cookies with 10 Taiwanese and 22 American subjects. Interestingly, for the cookies, while the same sucrose levels were rated as sweeter by the Taiwanese than by the Americans, the Americans found the sucrose to be more pleasant. These findings indicate that the system (solutions or solid foods) in which tastants are dispersed can have an impact on taste response (Bertino et al., 1983). The authors also noted that it was possible that differences in rating scores between cultures may be due to differing interpretations of verbal descriptors used in category rating scales rather than to differences in perceptual abilities per se. Depending on past dietary experience with tastes, terms such as "slightly sweet" or "extremely sweet" can hold different meanings.

In an effort to study the relationship between taste sensitivity, preferences and dietary history further, Druz and Baldwin (1982) studied these variables in Nigerian, Korean and American subjects. The researchers evaluated taste thresholds for the four basic tastes, preferences for these tastants in two food products (tomato juice and apple sauce) and the frequency of consuming certain foods. In terms of sensitivity, the thresholds of the three panels for the primary tastes in aqueous solution were similar. These results agree with those reported by Johannson et al. (1973) who determined that there was consistency in the sensitivity of subjects from Sweden, the United States of America, the Netherlands, and Poland. Druz and Baldwin (1982) also concluded that dietary history, that is, the frequency of food taste group consumption, was closely related to affective responses to tomato juice with sweet (r^2=0.99), sour (r^2=0.96), bitter (r^2=0.94) and salty (r^2=0.73) substances added. In terms of thresholds, it was found that individual thresholds for caffeine were directly associated with the frequency of consuming bitter foods (r^2=0.81). There were also significant cross-cultural differences concerning the levels of tastants preferred in the food products. The authors suggested that these data have significant implications for food companies wishing to diversify their international markets.

Johns and Keen (1985) studied the tasting ability of Aymara Indians living in the Bolivian Altiplano. Twenty-two Aymara Indians were tested for sensitivity to, and preferences for the four basic tastes. Dietary information was also collected. Sensitivities were similar to those of western populations but here, once again, there appeared to be some deviation in preference ratings. In particular, for sweetness, the Aymara rated 2 M glucose as more pleasant than 1 M glucose. This result differs from most populations which usually produce a sweetness preference function which levels off at a breakpoint of 1 M glucose. The Aymara also responded with lower pleasantness scores for sodium chloride, citric acid and quinine than western populations. These responses may be explained in part, by the environment in which the Aymara live. For example, the presence of potentially toxic bitter glycoalkaloids in the diet and the fact that on the Altiplano water sources are often extremely saline, may have produced an enhanced genetic or conditioned aversion to bitterness and saltiness (Johns and Keen, 1985). Similarly, the fact that the traditional diet is lacking in any sour component may explain the extremely low pleasantness ratings given for citric acid. In terms of their unusual preference for intense sweetness, this response to glucose may reflect a physiological need associated with adaptation to a high altitude (3950 m).

Studies Examining Diet History and Taste Function

It is reasonable to assert that the large degree of inter-population and intra-population variability in human taste sensitivity may be due, at least in part, to diet history. Many of the researchers in the aforementioned studies have pointed to this environmental input as an associative factor in cross-cultural taste response variability. Investigation in this area however, has yet to provide evidence of a clear relationship. Studies linking taste sensitivity and food intake have not demonstrated an association (Pangborn and Pecore, 1982; Mattes, 1985).

Food intake and taste function

Pangborn and Pecore (1982) studied threshold and preference scores for sodium chloride in water and tomato juice in a North American normotensive population. The subjects were classified into low, medium and high sodium intake groups according to a self-administered questionnaire. Although there was a trend indicating that the high intake group preferred higher amounts of salt, the authors were unable to find statistically significant differences among the intake groups with regards to hedonic or intensity responses. The results of the threshold measures also failed to indicate a clear relationship. To further study this relationship, Bertino et al. (1982) studied changes in salt taste sensitivity and pleasantness after subjects had consumed a low-sodium diet for 5 months. Using category scales, the investigators found that there was no significant effect of diet on intensity ratings of sodium in water solutions or soups, but that perceived saltiness of crackers increased significantly. In terms of affective responses, breakpoint preference concentrations (maximum pleasantness) of salt in solution were unaffected by the dietary manipulation. Breakpoints in soup and in crackers however, decreased markedly after intake of the low-sodium diet.

Mattes (1985) attempted to clarify some of the methodological issues associated with the failure to find meaningful evidence of diet-taste function relationships. Specifically, it was hypothesized that the use of taste thresholds rather than suprathreshold taste ratings, the use of a single indicator of gustatory function rather than a taste profile, the use of aqueous solutions rather than food systems and the use of unvalidated methods of dietary assessment may all be involved in the masking of a relationship between diet and gustatory function. Taste sensitivity, perceived intensity and preferred concentrations of sweetness and bitterness were assessed in aqueous solution and in beverages in a study using 35 subjects. These scores were then compared to diet measured as percentage of calories derived from sweet, sour, salty and bitter foods as determined by a 7 day diet record. No significant associations were found between thresholds, perceived intensities, or preferred concentrations and diet, whether the tastants were dispersed in water or in a beverage. It was determined however, that a taste profile including all three measures was able to account for approximately one-third of the variance in intake of sweet and bitter calories. Interestingly, the 7 day record was not able to provide evidence of an association between diet and taste function, which indicates that the lack of a demonstrable association in earlier studies is not due to deficient dietary assessment alone.

Food habits and taste function

Despite the inability of investigators to provide evidence of a relationship between quantified intake and taste function, several research groups have shown that there are links between food habits or food selection and tasting ability. The role of taste sensitivity in the acceptance or rejection of foods however, has not been entirely elucidated. Fischer et al. (1961) found after an examination of the thresholds and food dislikes of 48 subjects that sensitivity to 6-n-propylthiouracil (PROP) and quinine was related to the frequency of food dislikes. Glanville and Kaplan (1965) lent support for this association in a study of the food preferences of 187 subjects. It was found that there was a significant positive correlation between preferences for strong tasting foods and high taste thresholds for PROP and quinine (0.366 and 0.262). As in Fischer's study, the authors also found that there was a positive correlation between the number of foods disliked and increased taste sensitivity (Glanville and Kaplan, 1965). It was suggested that the existence of the PTC-PROP tasting gene may be related to the ability to taste bitter, toxic compounds in foods. Food likes and dislikes are influenced by a host of factors including those of a cultural and social nature. What is unclear after reviewing the literature, is whether taste sensitivity influences food preferences or whether diet history influences sensitivity to, and preferences for, the basic tastes.

The food frequency questionnaire

Food selection data is useful in a study of avoidance versus partiality for foods (Meiselman, 1986). The food frequency checklist is a common tool in the assessment of food selection. This method involves a survey type procedure where subjects are asked which foods are consumed with what frequency (Meiselman, 1986). Advantages of the food frequency method include ease of administration and analysis, ease of analysis by food group, low cost and minimal respondent burden (Medlin and Skinner, 1988). This last benefit was particularly relevant in the present study where subject burden in terms of participation in sensory evaluation sessions was heavy. The food frequency method has been shown to possess moderate validity in the assessment of individual and group intake and in the classification of individuals according to intake (Mullen et al., 1984; Willett et al., 1985).

TASTE MASKING EFFECTS OF FOODS

Taste response studied only in aqueous solution cannot be generalized to response in foods (Pangborn and Pecore, 1982; Bertino et al., 1982; Bertino et al., 1983). The complexities of foods including the interaction of texture, flavour and visual properties and the expectations about taste qualities will affect preferences for tastants in foods (Moskowitz et al., 1975). Sensitivity is also expected to decline due to these factors as well as the quantity of tastants reaching the taste receptors (Amerine et al., 1965). In early studies, Mackey and Jones (1954) found that recognition thresholds for the primary tastes were not related significantly to a judge's ability to sort foods adulterated with these tastes in order of increasing concentration. Similarly, Mackey and Valassi (1956) in an examination of tomato juice and custard found that the texture of a food (liquid, gel or foam) had a significant effect on taste response. It was determined that sweet, sour and salty tastants were easiest to detect in a liquid, followed by a foam, followed by a gel. Response to bitter tastants was unaffected by texture perhaps due to the lingering effect associated with this taste quality. It was also determined that sensitivity differed from food to food. Sodium chloride, sucrose and caffeine were easier to detect in the custard while tartaric acid was more evident in the tomato juice. As expected, thresholds in water were much lower than thresholds in foods. Specifically, twice and four times the threshold concentration of caffeine and sodium chloride were required to produce a response in the foods. More recent work includes the finding that the limonin (bitter) threshold in orange juice was six times greater than in water (Guadagni et al., 1973). Mattes (1985) determined that recognition thresholds for sweetness and bitterness were higher and more variable in beverage systems than in aqueous solution.

It is clear therefore, that a comparison between individuals or groups based on response to tastants in aqueous solution cannot be generalized to response in foods. Furthermore, screening for sensory panels on the basis of sensitivity in solutions does not ensure a judge's ability to discriminate tastants in foods.

POTATO FLAVOUR

As demonstrated, efforts to identify suitable panelists for a sensory panel should include an assessment of judges' ability to discriminate tastes in the food being investigated. In the present study, an examination of bitterness in potatoes is of particular interest due to the presence of naturally occurring bitter toxins in Andean potatoes.

It has been stated that in normal cooked potatoes, none of the four primary taste qualities is present (Solms and Wyler, 1979). There is however a distinct flavour associated with the potato. Solms and Wyler (1979) asserted that free amino acids and 5'-nucleotides occurring in cooked potatoes are important components, while the sugars glucose, fructose and sucrose do not contribute positively to the flavour. In fact, if these compounds occur in abnormally large amounts and a sweet taste is imparted to the potato, acceptability is decreased. Starch composes the largest fraction of the potato but contributes more to texture than taste. The most frequently noted off-flavour in potatoes is bitterness believed to be caused by glycoalkaloids (Sinden et al., 1976).

Effect of Glycoalkaloids on Potato Flavour

There is not an extensive amount of literature concerned with the taste of glycoalkaloids possibly due to the ethical dilemma associated with feeding potentially toxic compounds to human subjects. There have however, been a few studies. Sinden et al. (1976), in a study of the effects of glycoalkaloids on potato flavour, found that glycoalkaloid levels in excess of 14mg/100g fresh weight resulted in the perception of bitterness. It was also determined that a burning sensation was perceived after tasting tuber tissue with high glycoalkaloid content (ie. >22mg/100g). Furthermore, panelists reported a sore or scratchy throat that often persisted for several hours after tasting. The correlation coefficients were highly significant between glycoalkaloid content and bitterness (r^2=0.93) and burning (r^2=0.97). Zitnak and Filadelfi (1985) evaluated the flavour of α-solanine, α-chaconine and β_2-chaconine in pure solution using two tasters. The investigators described two responses to the glycoalkaloids including 1) a typical bitter taste and 2) a pain sensation characterized by a burning or peppery feeling. It was also noted that as the concentrations of glycoalkaloids increased, the bitter taste persisted for a shorter time and merged into the burning sensation. Other interesting findings include the result that solanine is about 4 times as bitter as caffeine and the observation that the "bitterburn" sensation characteristic of glycoalkaloids is due to the glycosides and not the free alkaloid.

A study related to the present investigation was completed by Johns and Keen in 1986. The researchers studied Aymara Indians in the Andean Highlands to determine if this population exhibited special abilities in the perception of, or preferences for glycoalkaloids in tubers. It was determined that the Aymara detect bitterness in potatoes with glycoalkaloid content in excess of 17mg/100g compared to North American subjects who detect bitterness at 14mg/100g. The authors speculated that this difference in perception may be due to the fact that in their resource-limited environment, the Aymara have developed a higher level of acceptance for glycoalkaloids. It was also shown that the Aymara are capable of making judgments of potato quality based on flavour. It must be noted however, that the rankings of potatoes were not correlated with total glycoalkaloids or with the pattern of individual glycoalkaloids. It appeared that factors such as dry matter content and texture may have played some role in the judgments by the Aymara. These determinants of potato quality will need to be elucidated as a part of the Andean project to ensure that any new techniques for detoxification do not adversely affect texture, visual aspects or other quality characteristics.

Preferences for Salt in Potatoes

Consumers from western cultures generally prepare potatoes with the addition of salt. Bennett and Hamilton (1981) determined in laboratory panels that judges preferred mashed potatoes with a salt concentration of 0.1 - 0.15 M. It was also determined that panelists were very sensitive to salt and were able to distinguish small differences in concentration even at levels below those considered 'salty'.

It is particularly important to note that salt may mask other flavours such as the bitterness of glycoalkaloids in potato (Mondy and Gosselin, 1988). Perception of, and preferences for salt in potatoes would be worthy of investigation in other cultures.

CONCLUSIONS

Cross-cultural differences in preferences for the four primary tastes and frequency of PTC tasting have been documented. The factors responsible for these differences are not well understood and genetics and environment may both play a role. Diet has been proposed as an important environmental element yet studies attempting to link diet and taste sensitivity have been largely unsuccessful.

Taste response studied only in aqueous solution cannot be generalized to response to tastants in foods. Thresholds have been shown to be lower in water than in foods. Also, cultural sensitivity and preferences for tastants in foods may depend on the degree of familiarity of the culture with the food under study. Therefore, in the Andean crops sensory research, the effect of potato flavour on taste response to the primary tastes should be examined. These effects should also be studied cross-culturally.

CHAPTER 3

COMPARISON OF TASTE SENSITIVITY IN SELECTED CANADIAN AND PERUVIAN POPULATIONS

INTRODUCTION

Cross-cultural variability in taste response has been shown through studies using phenylthiocarbamide (PTC) and compounds representing the four basic tastes. Differences in the frequencies of tasters of phenylthiocarbamide (PTC) in North American populations when compared to Andean populations in Ecuador and Peru, or to inhabitants of the Yucatan Peninsula in Mexico have been documented (Greene, 1974; Frisancho et al., 1977; Davis, 1978). Culturally influenced differences in sensitivity to, and preferences for, the four primary tastes have also been reported. Bertino et al. (1983) determined that Taiwanese students residing in the United States rated sucrose in aqueous solution as tasting sweeter and more pleasant than did American subjects. Johns and Keen (1985) determined that taste sensitivity of Bolivian Aymara Indians was similar to the sensitivity of western populations but that Aymara preferences differed. The Aymara exhibited higher pleasantness breakpoints for sucrose and responded with lower pleasantness scores for sodium chloride, citric acid and quinine.

It is unclear to what extent cross-cultural variability is environmentally or genetically controlled. Diet has been identified as an important environmental variable that may impact taste response (Johns and Keen, 1985; Bertino, 1983; Moskowitz, 1975). Druz and Baldwin (1982) found that in Nigerian, Korean and American subjects, thresholds for caffeine were directly related to the frequency of intake of bitter foods. There are however, very few cross-cultural studies that have measured the association between food selection and taste sensitivity.

The International Development Research Centre currently supports research on methods to improve the processing and marketability of Andean crops. The work is centred in Peru and Ecuador where crops such as bitter potatoes and quinoa are important sources of protein and calories for the people of the Andean highlands. Glycoalkaloids and saponins (naturally occurring toxins) are components of these crops, necessitating lengthy detoxification procedures before consumption. Changes to traditional processing methods could result in products that are unacceptable to Peruvian consumers, unless the sensory quality and consumer preferences are taken into account. Experience indicates that it would be advantageous to conduct some preliminary sensory evaluation in Canada. For this work to be of value however, we must ensure that results from our North American laboratory will be meaningful in the Peruvian Altiplano.

The comparability of the gustatory response of Canadians and Peruvians must be determined. Comparison of taste thresholds provides a useful starting point although it has been suggested that the use of thresholds is questionable as this indicator cannot be generalized to response at suprathreshold concentrations (Pangborn and Pecore, 1982; Bartoshuk, 1978). In the present investigation however, determination of minimum detectable concentrations is crucial, as the compounds of interest are potentially toxic.

Attempts to detect cross-cultural differences in detection thresholds are rare and have generally not found differences (Druz and Baldwin, 1982; Johansson et al., 1973). Some studies have looked at difference rather than detection thresholds or have used small panels with 8 untrained subjects per cultural group.

The purpose of the present investigation is to determine if differences exist in the detection thresholds of Peruvian and Canadian male and female university staff and students.

Specific objectives of the study were:

1) To determine and compare detection thresholds of Peruvians and Canadians for the four primary tastes.
2) To assess food selection patterns of the two cultural groups.
3) To examine the association between food selection and detection thresholds in each group.

MATERIALS AND METHODS

Materials

Chemicals were obtained from the following sources: glucose, the Wine Baril, Winnipeg, Manitoba; sodium chloride, Mallinckrodt, Inc., Paris, Kentucky; quinine sulphate, British Drug Houses Ltd., Poole, England; citric acid, J.T. Baker Chemical Co., Phillipsburg, New Jersey.

Methods

Subjects

Subjects tested were students and staff from the Universidad de San Agustin in Arequipa, Peru and the University of Manitoba, Winnipeg, Canada. Subjects consisted of 21 Peruvians aged 18 to 38 (11 males and 10 females) and 20 Canadians aged 21 to 41 (7 males and 13 females).

Preparation of solutions

Six concentrations of solutions were prepared as follows: serial half dilutions from stock solutions of .01 M sodium chloride (NaCl) and .0000125 M quinine sulphate (QSO_4) and serial quarter dilutions from .0002 M citric acid and .085 M (Canada) and .07 M (Peru) glucose. Stock solutions were prepared 24 hours before testing and stored at room temperature (Canada: 22°C, Peru 20°C) overnight. Dilutions were made the morning of tests. Due to the availability of distilling systems, solutions were prepared using double glass distilled water in Peru and tap distilled water in Canada.

Threshold measurements

Detection thresholds were determined using ASTM method E679-79, a forced choice ascending concentration method of limits. This method is a triangle method of threshold measurement where panelists are asked to identify the odd sample from three served. The odd sample contains the tastant under study at near threshold concentrations. In this study for each threshold determination, panelists were served six triangles of samples arranged such that the odd samples in the triangles were tasted in ascending concentration. Three measurements were completed for each panelist for each compound. The first measurement was considered to be training and was not included in the analysis. Panelists completed two tests per day with a 10 - 15 minute break between tests during which unsalted crackers and water were served. The pairing of the two compounds tested each day was balanced such that each compound was tested in tandem with each of the remaining compounds. The order of presentation of the paired tests was randomized for each panelist.

For the threshold tests, the serving order within each triangle was randomized between panelists. For each panelist, the odd sample was presented equally in the first, second and third positions within a given test to eliminate positional bias. Panelists were instructed to expectorate samples and to rinse with water in between sets of samples. The method of tasting was standardized during the training session such that subjects would move the sample around the mouth and over the tongue. Samples of 15 ml were presented at room temperature in 30 ml plastic cups in Canada and in 90 ml plastic cups in Peru. Samples were coded with 3 digit random numbers. In Canada, evaluation took place in individual sensory booths under yellow light. In Peru, evaluation took place at laboratory counters in individual wooden portable partitions under natural light.

Prior to testing, all subjects participated in an introductory training session where the importance of sensory analysis and the project was discussed. Also at this time, the method and the ballot (Appendices 1,2) were explained and samples with suprathreshold concentrations of the four basic tastes (QSO_4 = .0002 M, NaCl = .25 M, glucose = .1 M, citric acid = .0008 M) were presented to aid panelists in the identification of tastes.

Taste identification

After tasting the last group of samples in each test, taste identification was measured by a forced choice question at the bottom of the ballot (Appendices 1,2).

Food selection measurement

Food selection was evaluated using an abbreviated food frequency checklist. Two separate culture-specific food frequency questionnaires were developed for Winnipeg, Canada and Arequipa, Peru (Appendices 3,4). The questionnaire was designed to yield information regarding the frequency of consumption of foods classified according to primary taste quality. For each population, a list of 30 to 40 foods which exhibit the quality of being sweet, sour, bitter or salty was generated. For the Peruvian population, frequency of intake of hot foods and Andean crops was also surveyed. The respective questionnaires were pre-tested with a sample of 8 to 10 individuals from each population to evaluate clarity and suitability.

Statistical analysis

Threshold concentration for a given test was calculated as the geometric mean of the concentration at which the last miss occurred and the next higher concentration. Geometric means were logged (log n) prior to analysis as recommended by ASTM and because early analysis indicated that the variance of the data was associated with the mean. The first measurement was discarded and the mean of the second and third measures was taken as the best estimate of individual thresholds. The mean of the individual thresholds was taken as the panel threshold. Differences in means of the $\log_n$ data were analyzed by analysis of variance with group, sex and group*sex as the effects. Antilogs of the mean $\log_n$ thresholds were reported as the mean detection thresholds. This value is equal to the geometric mean of the untransformed data.

Food frequency data were analyzed after converting frequency of food intake to number of times per month. Frequencies were then summed to give exposures to bitter, salty, sweet and sour stimuli for each panelist within a group. Spearman (ranked data) correlations were generated within each group to examine associations between food selection and taste thresholds.

RESULTS AND DISCUSSION

Detection Thresholds

Peruvian and Canadian mean detection thresholds are summarized in Table 3.1. The threshold values were similar for the two groups, although the mean Peruvian thresholds for glucose and citric acid were higher than the Canadian values. The threshold values for the basic tastes are generally lower than those reported in the literature (Table 3.2) except for quinine sulphate which falls within the reported range of .0004 to .011 mM. Citric acid, glucose and sodium chloride thresholds are considerably below those previously reported. Citric acid values have been reported as falling between .4 and 1.8 mM compared to our values of .04 and .07 mM. Sodium chloride values have been reported in the area of 10 mM compared to our values of 1.3 to 1.8 mM. Glucose thresholds are reported as falling between 40 and 90 mM compared to our results of 14 to 21 mM. This increased sensitivity in detecting minimum detectable concentrations may be due to the use of trained panelists, repeated measures and a rigorous method of threshold determination. McBride and Laing (1979) reported that the use of a triangle method of threshold

Table 3.1: Peruvian and Canadian mean detection thresholds for the primary tastes

GROUP	QUININE SULPHATE (mM)	SODIUM CHLORIDE (mM)	GLUCOSE (mM)	CITRIC ACID (mM)
PERUVIANS	0.0010	1.8255	21.6684	0.0705
CANADIANS	0.0013	1.3143	14.0265	0.0423

Table 3.2: Range of human detection thresholds for the primary tastes

TASTANT	RANGE (mM)	MEDIAN (mM)
QUININE SULPHATE (BITTER)	.0004 - .011	.008
CITRIC ACID (SOUR)	.40 - 1.79	.72
GLUCOSE (SWEET)	40 - 90	80
SODIUM CHLORIDE (SALTY)	1 - 80	10

Adapted from Pfaffman (1959) as cited in Amerine (1965) testing resulted in sodium chloride thresholds of .003 M and that significant training occurs with this method. It was concluded that this method is a sensitive means of threshold measurement that avoids problems associated with semantics and scaling.

The difference in magnitude of thresholds for both groups for bitterness compared to the remaining taste qualities should be noted. Bitterness values fall in the area of .0010 to .0013 mM as compared to 15 to 20 mM for sweetness. The remarkable human sensitivity to bitter stimuli can be explained as a genetic or conditioned aversion to bitter toxins such as alkaloids (Guyton, 1976). It is also interesting to note that sensitivity appears to follow affective response with bitterness at the bottom of the scale, sweetness at the top and sourness and saltiness in between. The pleasantness of the tastes follow this same pattern in western populations with bitterness and sourness described as unpleasant, salt described as pleasant at low concentrations but unpleasant at high concentrations and sweet as pleasant (Moskowitz et al., 1975).

Analysis of variance statistics are found in Table 3.3 with significant effects illustrated in Figures 3.1 and 3.2. In terms of group effects, Peruvians and Canadians differed significantly in sour perception ($p = 0.015$) and showed a difference in sweet perception at a probability level of 0.055. Significant sex effects were found in salt perception (p = 0.008) and sour perception (p = 0.020). No significant group*sex interactions were apparent indicating that the sex effect was consistent in both locales.

A breakdown of thresholds according to cultural group and sex for the basic tastes is presented in Tables 3.4, 3.5, 3.6 and 3.7. Bitter perception did not differ between the two cultural groups (Table 3.4). This result is not surprising as other researchers have also failed to show cultural differences in quinine sulphate and caffeine sensitivities (Druz and Baldwin, 1982; Johns and Keen, 1985). Peruvian and North American differences in bitter sensitivity have mainly consisted of differences in frequency of PTC tasting among rural Indian groups and North American urban groups (Frisancho et al., 1977; Greene, 1974). Ability to taste PTC does

Table 3.3: Analysis of variance mean squares and associated probabilities for taste thresholds

	QUININE SULPHATE	SODIUM CHLORIDE	GLUCOSE	CITRIC ACID
GROUP	1.201 (0.377)	0.181 (0.641)	1.817 (0.055)	1.985 (0.015)
SEX	2.430 (0.212)	6.328 (0.008)	0.324 (0.409)	1.788 (0.020)
GROUP*SEX	0.847 (0.458)	1.649 (0.164)	0.506 (0.303)	0.181 (0.445)
ERROR	1.504	0.820	0.465	0.305

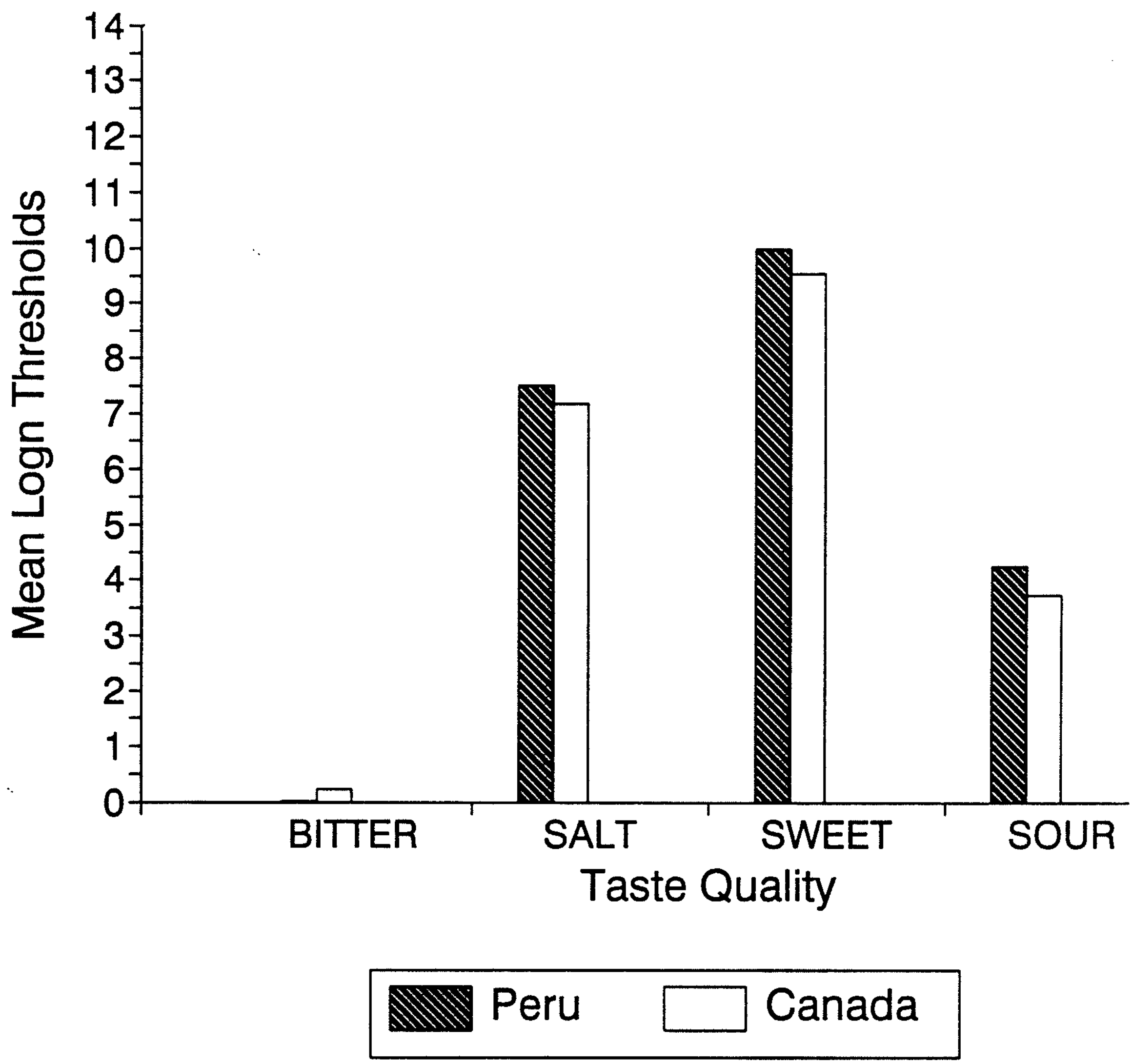

Figure 3.1 Comparison of Mean Peruvian and Canadian Detection Thresholds for the Primary Tastes

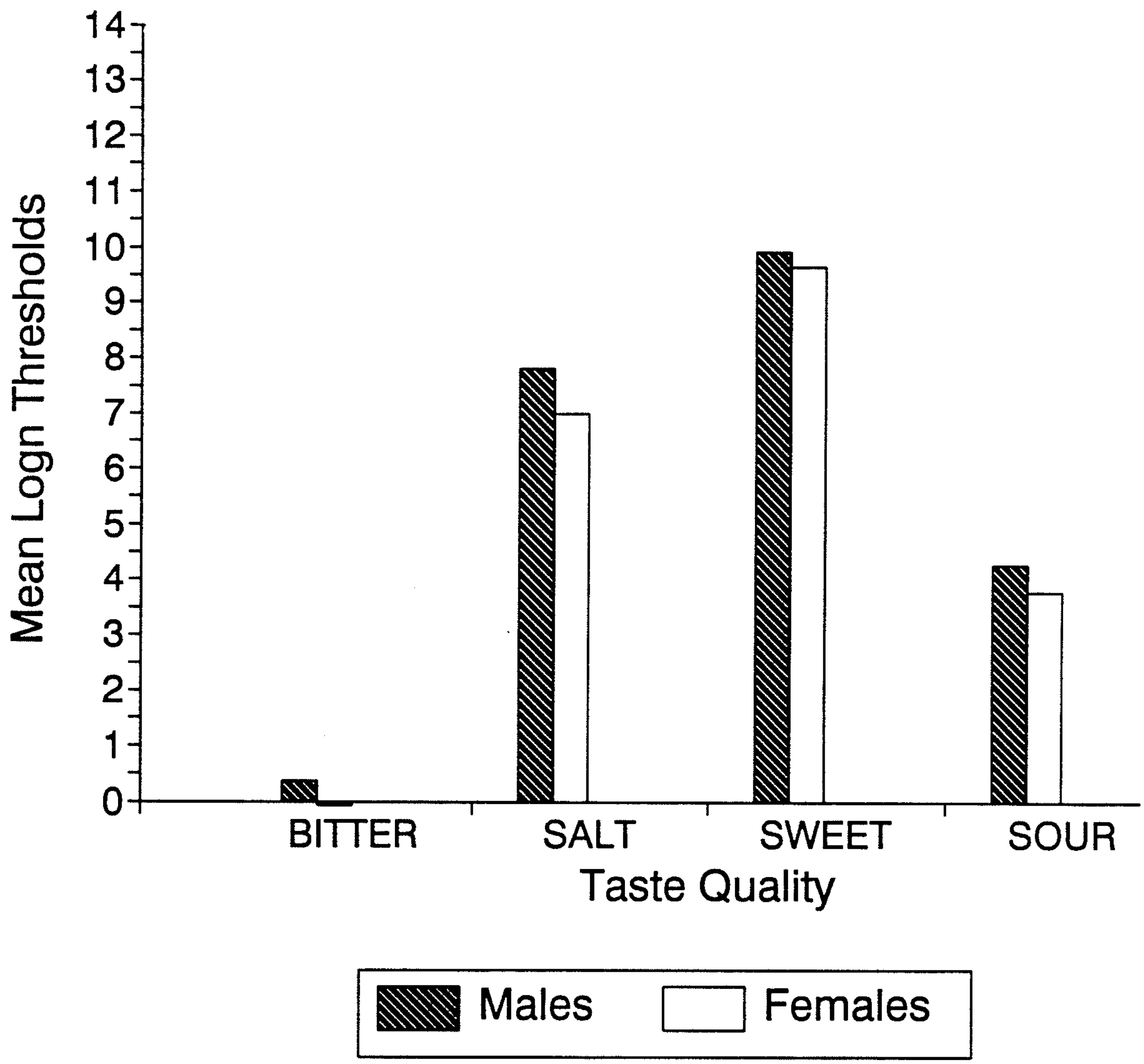

Figure 3.2 Comparison of Mean Male and Female Detection Thresholds for the Primary Tastes

Table 3.4 Mean quinine sulphate detection thresholds for Peruvians and Canadians

GROUP	MEAN LOGn THRESHOLD (mM)[1]	STANDARD DEVIATION	MEAN THRESHOLD (mM)[2]
PERUVIANS (M+F)	-6.8945	1.2129	0.0010
CANADIANS (M+F)	-6.6673	1.2421	0.0013
MALES (P+C)	-6.5458	1.2710	0.0014
FEMALES (P+C)	-6.9698	1.1675	0.0009
PERUVIAN MALES	-6.7971	1.0157	0.0011
PERUVIAN FEMALES	-7.0016	1.4486	0.0009
CANADIAN MALES	-6.1509	1.6001	0.0021
CANADIAN FEMALES	-6.9454	0.9609	0.0010

1 means of natural logs of detection threshold concentrations (mM)

2 antilogs of $\log_n$ thresholds (see footnote 1) = geometric mean of molar concentrations

Table 3.5 Mean sodium chloride detection thresholds for Peruvians and Canadians

GROUP	MEAN LOGn THRESHOLD (M)[1]	STANDARD DEVIATION	MEAN THRESHOLD (M)[2]
PERUVIANS (M+F)	-6.3059	0.8638	.0018
CANADIANS (M+F)	-6.6344	1.0996	.0013
MALES (P+C)	-6.0111	0.9632	.0024
FEMALES (P+C)	-6.8223	0.8682	.0011
PERUVIAN MALES	-6.1180	0.7804	.0022
PERUVIAN FEMALES	-6.5126	0.9437	.0015
CANADIAN MALES	-5.8430	1.2489	.0029
CANADIAN FEMALES	-7.0606	0.7566	.0009

1 means of natural logs of detection threshold concentrations (M)

2 antilogs of $\log_n$ thresholds (see footnote 1) = geometric mean of molar concentrations

Table 3.6 Mean citric acid detection thresholds for Peruvians and Canadians

GROUP	MEAN LOGn THRESHOLD (mM)[1]	STANDARD DEVIATION	MEAN THRESHOLD (mM)[2]
PERUVIANS (M+F)	-2.6539	0.6620	0.0705
CANADIANS (M+F)	-3.1626	0.4900	0.0423
MALES (P+C)	-2.6135	0.6696	0.0733
FEMALES (P+C)	-3.1278	0.5083	0.0438
PERUVIAN MALES	-2.3849	0.6010	0.0921
PERUVIAN FEMALES	-2.9497	0.6220	0.0523
CANADIAN MALES	-2.9729	0.6498	0.0512
CANADIAN FEMALES	-3.2648	0.3698	0.0382

1 means of natural logs of detection threshold concentrations (mM)

2 antilogs of $\log_n$ thresholds (see footnote 1) = geometric mean of molar concentrations

Table 3.7 Mean glucose detection thresholds for Peruvians and Canadians

GROUP	MEAN LOGn THRESHOLD (M)[1]	STANDARD DEVIATION	MEAN THRESHOLD (M)[2]
PERUVIANS (M+F)	-3.8319	0.6360	.0217
CANADIANS (M+F)	-4.2668	0.7252	.0140
MALES (P+C)	-3.8931	0.7999	.0204
FEMALES (P+C)	-4.1621	0.6183	.0156
PERUVIAN MALES	-3.6365	0.4854	.0263
PERUVIAN FEMALES	-4.0468	0.7342	.0175
CANADIAN MALES	-4.2964	1.0534	.0136
CANADIAN FEMALES	-4.2508	0.5264	.0142

1 means of natural logs of detection threshold concentrations (M)

2 antilogs of $\log_n$ thresholds (see footnote 1) = geometric mean of molar concentrations

not appear to be related to quinine sensitivity suggesting that two "bitter" receptor sites may exist (Hall et al., 1975). In the present study, both cultural groups were urban where diet was not restricted.

Salt detection thresholds are presented in Table 3.5. Again, cultural differences were not found. This result is expected as salt sensitivities have been shown to be consistent among locales and cultural groups (Johannson et al. 1973; Druz and Baldwin, 1982). A statistically significant sex effect was present with women possessing lower thresholds than men. This same effect was present in sour perception. Lower thresholds (increased sensitivity) in females agrees with past findings in the literature (Bertino et al. 1983; Doty, 1978).

There was a significant cultural difference shown for sour taste thresholds. Table 3.6 indicates that Peruvians had higher thresholds than Canadians. Johns and Keen (1985) reported that Bolivian Aymara Indians possessed greater acuity and had lower pleasantness responses for citric acid compared to western populations. Conversely, in a study carried out by Moskowitz (1975), East Indian labourers rated sourness as being more pleasant than western populations. The absence of sour foods in the Aymara diet and heavy usage of sour foods in the East Indian rural diet may have produced the differences in perception from the western group.

A borderline ($p = .055$) statistically significant difference was also observed for sweet (glucose) perception. Table 3.7 indicates that Peruvians had higher thresholds than Canadians. This result differs from those reported by Johns and Keen (1985) who reported that Aymara Indians did not differ significantly from western populations in sensitivity to supra-threshold concentrations of glucose. The authors did indicate however, that the Aymara Indians rated glucose as more pleasant than western groups. The difference in sweetness reported presently must be qualified. During preliminary testing in Winnipeg, it was determined that the glucose concentrations used in Arequipa were too low as many Canadian subjects could not detect the most concentrated sample (0.7 M). It was concluded that the Winnipeg subjects were less sensitive and the scale was raised to a stock solution of 0.85 M. After completion of the study however, analysis indicated that the Winnipeg mean threshold was lower than that obtained in Arequipa. Analysis of replications indicated that there was a significant training effect in the Winnipegers compared to the Arequipans during the first replication. The Canadian mean threshold dropped dramatically between the first two replications from .033 M to .0167 M compared to a slight increase in the Peruvian mean threshold from .0247 M to .0255 M. It is possible that the significant difference in sweetness thresholds may have been an artifact of the method and the concentrations used. With this type of method, where high measurement sensitivity is desired, concentration scales and degree of training should be monitored carefully.

Food Selection

Spearman correlations were generated for each group to identify associations between mean individual logged thresholds and selection of bitter, salty, sweet and sour foods (Table 3.8) In the Peruvian group, no significant correlations were found. In the Canadian group, a significant correlation was found between salt exposure and logged salt thresholds (r^2 = 0.557, p = .011) and sour exposure and logged sour thresholds (r^2 = -0.497, p = .026). The different direction of the relationships is interesting. The direct (positive) relationship between ranked logged threshold and ranked exposure to salty foods indicates that as threshold decreases (sensitivity increases), selection of salty foods decreases. Conversely, for sourness, as threshold decreases, exposure to sour foods increases. This latter relationship is contrary to that expected given that sourness is generally

Table 3.8: Spearman correlations for detection thresholds and dietary exposure to the primary tastes in Canadians and Peruvians

	BITTER	SALT	SWEET	SOUR
PERU	-0.082	-0.172	-0.094	0.271
CANADA	-0.084	0.557*	0.290	-0.497*

* probability < 0.05

considered to be an unpleasant stimulus in western diets (Moskowitz et al., 1975). That is, a decrease in exposure, rather than an increase, would be expected to accompany an increase in sensitivity as in the case of saltiness. The results are not readily explained.

It would be interesting to see if diet was responsible for cross-cultural differences in sweet and sour perception as hypothesized by Moskowitz et al. (1975) and Johns and Keen (1985). Due to the culture-specific nature of the food frequency questionnaires, it was not possible to compare sour exposure in Arequipans and Winnipegers directly. A few distinctly sour foods appeared on both instruments however, and these exposures could be compared. Mean exposures for all foods that appeared on both questionnaires are found in Table 3.9. Exposure to sour foods differed. Lemons were ingested, on average, 25 times per month by Arequipans compared to 2.5 times by Winnipegers, and lemonade was ingested 33 times per month by the Peruvians compared to 3.75 times by the Canadians.

Examination of comparable sweet foods in both diets also showed differences in intake. While consumption of cake, cookies and ice cream was similar, Peruvians had a much higher consumption of candy at 22.14 times per month compared to 2.55 for the Canadian group. Intake of chocolate was 8.5 times per month in the Peruvians compared to 3.7 in the Canadians. Habitual diet may affect pleasantness scores, and also affect

Table 3.9 Mean Peruvian and Canadian Exposures to Foods Representing the Primary Tastes

FOOD	PERUVIAN EXPOSURE (TIMES/MONTH)	CANADIAN EXPOSURE (TIMES/MONTH)
SOUR		
ORANGES	5.57	4.40
ORANGE JUICE	6.57	7.40
LEMONS	24.67	2.45
LEMONADE	33.19	3.75
RED WINE	0.19	0.95
VINEGAR	6.14	4.95
SWEET		
CAKE	1.67	2.75
COOKIES	8.48	8.95
CANDY	22.14	2.55
CHOCOLATE	8.50	3.70
ICE CREAM	6.67	5.30
SOFT DRINKS	9.90	18.70
BITTER		
COFFEE	17.24	51.55
TEA	53.14	13.30
BEER	1.52	3.35
SALTY		
HAM	2.00	2.70
BACON	0.48	1.55
SOYA SAUCE	1.71	2.05

threshold sensitivity (Moskowitz et al., 1975; Bertino et al., 1983; Johns and Keen, 1985).

The means presented in Table 3.9 also show that intake of bitter foods was not noticeably different in the two locales possibly explaining the lack of a statistical difference in bitter thresholds. Intake of bitter foods appeared to be equivalent except for an emphasis on tea as a daily beverage in Peru compared to coffee in Canada. Furthermore, intake of the bitter Andean crops including bitter potatoes (or chuno) and quinoa was not particularly common in Arequipa. If political conditions improve in Peru, a comparison of sensitivity and diet in rural communities processing and consuming these crops would be advisable and may show clearer differences.

Taste Identification

The results of the taste identification question are found in Table 3.10. In both populations, the fewest errors were found in the identification of quinine sulphate as bitter with 96.8% correct responses in Peruvians and 93.3% in Canadians. This may reflect the exceptional human sensitivity to bitterness as well as the training session during which subjects were presented a clear representative of the tastants. Confusion occurred with sodium chloride with less than 80% correct identifications in both populations. The most common incorrect response was sweet or dulce. This finding agrees with Amerine et al.'s (1965) statement that at threshold concentrations, sodium chloride may impart a sweet taste and only possesses the characteristic 'salty' taste at supra-threshold concentrations. Confusion also occurred with glucose with both populations identifying the compound as possessing a bitter taste about 12% of the time.

The only clear separation in naming ability between the groups occurred interestingly again in sourness. The Peruvians correctly identified citric acid as sour (acido)

Table 3.10: Percent frequency of taste identification in Peruvians and Canadians

STIMULUS		TASTE IDENTIFICATION (%)				TOTAL
		BITTER (AMARGO)	SALTY (SALADO)	SWEET (DULCE)	SOUR (ACIDO)	
QUININE SULPHATE						
	P	96.8	0.0	1.6	1.6	100.0
	C	93.3	1.7	0.0	5.0	100.0
SODIUM CHLORIDE						
	P	1.6	79.4	14.3	4.7	100.0
	C	1.7	78.3	13.3	6.7	100.0
GLUCOSE						
	P	12.7	0.0	85.7	1.6	100.0
	C	11.7	3.3	80.0	5.0	100.0
CITRIC ACID						
	P	3.2	1.6	6.3	88.9	100.0
	C	10.0	5.0	5.0	80.0	100.0

approximately 90% of the time compared to 80% in the Canadians. There are two possible explanations for this difference. Firstly, the increased correct identification may reflect the aforementioned increased intake of, and familiarity with, citrus fruits in Arequipans. Related to this explanation is the second factor which may be a simple difference in linguistics. Johns and Keen (1985) found that the Bolivian Aymara had an expanded nomenclature for bitterness possibly due to their exposure to glycoalkaloids and saponins. It is possible that the Arequipans' increased exposure to citrus foods has led them to possess a clearer concept of 'acido' compared to Winnipegers' concept of 'sour'. The most frequent incorrect response to citric acid in Canadians was 'bitter' indicating the common bitter/sour confusion. Contrary to O'Mahoney and Manzano Alba's (1980) results, the frequency of bitter/sour confusions was more frequent in English speakers than the amargo/acido confusion in Spanish speakers.

GENERAL DISCUSSION

Evidence for cross-cultural differences in taste sensitivity has mainly been produced in the area of frequency of tasters of phenylthiocarbamide (PTC) (Doty, 1986; Davis, 1978; Greene, 1974). Ability to show differences in threshold values or supra-threshold intensity have been limited (Johns and Keen, 1985; Bertino et al., 1983). The present investigation is unique therefore, in its ability to demonstrate cross-cultural differences in threshold values for the primary tastes. If the measured differences reflect true variability in sensitivity, the ability to detect these differences may be due to the use of trained panels in the present investigation as well as, the use of a rigorous method of threshold testing.

The possible confounding factor of water type requires discussion. Due to quality and availability of distilling systems in the two locales, solutions were prepared with double glass distilled water in Peru and with tap distilled water in Canada. Bartoshuk (1978) has determined that depending on preceding solutions, water may take on any of the four basic tastes, and may affect threshold testing. It was also noted however, that the effect of water taste would be minimized if subjects rinsed adequately between samples. In the present investigation, subjects were instructed to rinse with water in between triangles. Furthermore, with the triangle method of threshold testing, subjects rinse with two blank samples per sample with solute. It is probable that the water taste effect would be minimized. Bertino et al. (1983) discussed the role of water as a confounder in their study. The investigators studied the effects of using deionized water versus distilled water on intensity and pleasantness ratings of sucrose and sodium chloride. It was concluded that water type was probably not responsible for the measured cultural effects on gustatory response. In our study, it seems odd that differences would only be found in glucose and citric acid thresholds and not in sodium chloride and quinine sulphate thresholds, if water type was responsible for cultural effects. Interestingly, Canadian panelists observed that the tap distilled water occasionally tasted bitter, yet cultural differences for quinine sulphate were not evident. It is possible that since the threshold tests involved a simple, detection triangle test with ample rinsing, that panelists quickly adapted to the taste of the water and were able to disregard the taste of the blank samples when attempting to detect "odd" samples.

The present investigation was important in its attempt to measure the hypothesized effect of diet on cross-cultural differences in taste sensitivity. The failure to produce concrete results of this relationship reflect the difficulties encountered by other investigators (Pangborn and Pecore, 1982; Mattes, 1985). Shortcomings of this study include the use of unvalidated instruments in the measurement of food selection and the possible difference in the ability of the investigator (Canadian) to develop an equally valid instrument for the Arequipan and Winnipeg diet despite consultation with Arequipan residents. As demonstrated in our results however, difficulties in generating comparable, valid instruments for different cultures may be circumvented by identification and comparison of foods present in both diets which clearly represent the tastes of interest (e.g. candy, chocolate, vinegar, lemons, salted nuts, coffee).

The failure of this study, along with others, to provide evidence of the diet/sensitivity relationship suggests that a strong association may not exist. The factors affecting food selection are numerous and include genetic inputs (e.g. race, sex, age, acuity), physiological factors (e.g. caloric and nutrient needs) and psychological factors (e.g. economic availability, habits, nostalgia, intellect, religion) (Sinki, 1988). It is possible that these elements supersede the role of taste thresholds in food selection.

CONCLUSIONS

The present study indicated that taste sensitivity is similar in the Peruvian and Canadian subjects studied although statistically significant differences were found to exist in sweet and sour perception. Canadians were found to possess lower thresholds (higher sensitivity) for glucose and citric acid than the Peruvians. Attempts to explain this variation by correlating taste sensitivity and food selection data measured by food frequency checklists were unsuccessful. Examination of singular foods present in both cultures however, may circumvent problems in the design of equally valid questionnaires for two cultures. A particularly heavy usage of lemon and lemonade in the Peruvian group compared to the Canadian group was discovered from this type of data and may help to explain the cultural difference in sour perception.

Canadians and Peruvians were shown not to differ in sensitivity to bitterness, suggesting that Canadian panelists would be able to distinguish this taste if sensory research on Andean crops were to take place in Canada. The similarity in bitter perception was not surprising given the urban nature of both populations. Research conducted in rural communities producing and processing bitter potatoes might reveal differences in sensitivity between urban and rural Peruvians.

The reported sex effects on taste perception for both cultural groups suggests that sensory panels should be balanced in terms of the sexes such that the consumer market can be adequately represented.

CHAPTER 4

PERUVIAN AND CANADIAN GUSTATORY RESPONSE TO BITTERNESS AND SALT IN INSTANT POTATO PUREE

INTRODUCTION

In the impoverished Andean region, the diet of indigenous people has been largely dependent on a small number of crops of which quinoa, a protein rich grain, and bitter potatoes are especially important. Traditional processing of these two staples has as a major goal the removal of naturally occurring toxins, glycoalkaloids and saponins, to permit safe consumption of the processed foods as well as reduction of the bitter taste. Methods used for bitter potatoes consist mainly of a leaching step for detoxification and a sun-drying step for preservation. The process is time and labour intensive, unhygienic and has been indicated as a factor in the development of arthritis in processors. The International Development Research Centre is supporting research to introduce improved appropriate technology for traditional potato processing. An essential element of the criteria used to determine success of the processing techniques is that the product be acceptable for home consumption and domestic markets.

Sensory criteria must be established to monitor acceptability of processing changes. It would be an advantage to conduct some aspects of the process development in Canada, and sensory criteria would need to be applicable in both Peruvian and Canadian laboratories. It has been shown however, that cross-cultural differences exist in ratings of taste intensity and pleasantness (Moskowitz et al., 1975; Bertino et al., 1983; Druz and Baldwin, 1982). It has also been shown that gustatory response to tastants in aqueous solution does not predict response in food products (Pangborn and Pecore, 1982). Bertino et al. (1983) determined that students of Taiwanese descent rated sucrose in solution as more pleasant than American students who preferred sucrose in a solid food (cookies). It was suggested that the carrier dependent nature of cross-cultural differences in preferences may be related to the form in which the taste is normally encountered in the culture. For instance, the Taiwanese diet contains a sweet water based drink while the American diet contains sweet solid foods such as cookies and cakes. Due to these considerations, a study examining the ability of Canadians and Peruvians to detect tastants in potatoes is warranted.

Detection and recognition thresholds in food products are considerably higher than thresholds in aqueous solution (Guadagni et al., 1973; Mattes, 1985; Pangborn and Pecore, 1982). It has also been reported that the degree of masking for the primary tastes will differ as a function of the type and texture of the food. Mackey and Valassi (1956) determined that salty, sweet and bitter tastants were more readily detected in custard, while a sour tastant was more readily detected in tomato juice. The degree of masking of bitter and salty tastants in potato may differ due to the difference in affective quality of the tastants (salt is pleasant, bitter is unpleasant). Furthermore, this differential in masking may vary cross-culturally.

A study of preference ratings for various concentrations of tastants is also necessary as research in the past has indicated that sensitivity scores do not correlate well with preference scores (Mattes, 1985). Cross-cultural differences may also become more apparent as cultural variability has usually been reported with respect to hedonic response rather than sensitivity (Moskowitz, 1975; Johns and Keen, 1985).

The purpose of the present investigation was to determine Peruvian and Canadian detection thresholds for salt and bitter tastants in potato puree, and to compare these with thresholds in aqueous solution to determine the extent of masking. A further objective was to examine the relationship between detection thresholds and hedonic scores for these tastants in potato puree.

The specific objectives of the study were:

1) To measure detection thresholds for bitter and salty tastants in an instant potato puree in Canadian and Peruvian subjects.
2) To measure and compare taste masking effects of potato puree in the two cultural groups.
3) To measure Canadian and Peruvian hedonic response to bitter and salty tastants in potato puree.

4) To examine the association between detection thresholds and hedonic ratings for bitter and salty tastants in potato puree.

MATERIALS AND METHODS

Materials

Comparable but different instant potato products were available in the two locales, therefore products used for the tests were Knorr's Potato Puree, Knorr, U.S.A. in Peru and in Canada, Carnation Real Potato Flakes, Carnation, Canada. A list of ingredients for both products is found in Appendix 5. Potato products in both locales were prepared with commercial pasteurized whole milk (Peru = 3 % fat, Canada = 3.3 % fat) purchased in local supermarkets. Sodium chloride was supplied by Mallinckrodt, Inc., Paris, Kentucky, and quinine sulphate was supplied by British Drug Houses, Ltd., Poole, England.

Methods

Subjects

The populations tested were sub-sets of the samples used for the threshold determinations in Experiment #1. Subjects consisted of 16 Peruvians aged 18 to 38 (10 males and 6 females) and 15 Canadians aged 21 to 41 (5 males and 10 females). All subjects were non-smokers. One Peruvian subject was unavailable for hedonic testing, reducing the Peruvian sample size to 15 for that phase of the study.

Preparation of samples

In order to incorporate tastants into the potato puree, solutions of quinine sulphate and sodium chloride were first prepared, at appropriate concentrations. These solutions were used to replace the water portion of the formula. In both locales the solutions consisted of six half dilutions from stock solutions of .000055 M quinine sulphate and .048 M sodium chloride. The formulas used in the different locales were as follows:

Peru:	62.5 g potato flakes
	250 ml solution (glass distilled water)
	125 ml milk (3% fat)
Canada:	70.0 g potato flakes
	250 ml solution (tap distilled water)
	125 ml milk (3.3% fat)

The use of different amounts of potato flakes was necessary to produce products with similar textural properties.

Due to limited laboratory equipment in Peru the samples were prepared differently in the two locales. In Peru water was brought to a boil in a 1 L aluminum pot using an electric portable stove. The pot was then removed from the heat and the potato flakes and milk were added. The product was manually mixed for 30 seconds with a wooden spoon. The mixture was allowed to rest for 30 seconds and then was mixed for a further 10 seconds as per package directions. The same procedure was used in Canada except that glass pots were used in place of aluminum pots and a full-size electric stove was used. Samples were prepared the day before testing and were refrigerated (2°C) overnight in 1 L plastic Tupperware containers. Samples were allowed to reach room temperature (Peru = 18°C, Canada = 21°C) the following day just prior to sensory testing.

Threshold measurements

Detection thresholds were determined using the same procedure as Experiment #1, ASTM method E679-79. This method is described as a forced choice ascending method of limits and is a triangle method of threshold testing. The same test design was used as in Exp. 1. One threshold determination test for each tastant (quinine sulphate and sodium chloride) was conducted at one panel session for each panelist. A 10 - 15 minute break was taken between tests. Each panelist attended two sessions and so completed two threshold tests for each tastant. In light of the fact that all subjects were familiar with the sensory procedure, only one training or warm-up session was held in order to familiarize the panelists with the potato product. Training samples were adulterated with the salt solutions.

The same sensory panel procedure and conditions were used as Exp. 1 with the following modifications. The ballot (Appendices 6,7) was changed to allow subjects to swallow the samples if desired, and subjects were instructed to rinse with water in between samples instead of triangles. The taste identification task was also removed from the form. The portion size was approximately 30 g served in 60 ml plastic cups with lids. Samples were presented with rinse water, plastic teaspoons, serviettes, and expectoration cup with lid.

Hedonic testing

Potato samples used for hedonic testing were the same as the samples used for threshold measurements except that concentrations of quinine sulphate and sodium chloride were at suprathreshold levels. Canadian and Peruvian subjects rated potatoes prepared with .00002, .00003, .000045 and .0000675 M quinine sulphate and .009, .018, .036 and .072 M sodium chloride. All measurements were made using a 9-point hedonic scale (Appendices 8,9). As the addition of salt is recommended on both the Knorr's and Carnation packages, .70g sodium chloride (.048 M) was added to all the quinine sulphate solutions before the potato puree was mixed. Sample preparation steps were identical to those for the threshold measurements, and testing was completed under the same sensory conditions. Subjects completed both tests (quinine sulphate and sodium chloride) on the same day and tests were conducted once.

Statistical analysis

Given the use of different potato products in Canada and Peru, all analyses were carried out separately for the two cultural groups. All data, initially reported in molar concentrations, (ie. potato and water thresholds for quinine sulphate and sodium chloride) were converted to ppm to permit measuring of masking effects (Appendix 10).

Threshold concentrations for a given test were determined using logged (log n) data as described in Exp.1. Again, thresholds for a panelist were taken as the mean of the two threshold measurements. The mean of the individual thresholds was taken as the panel threshold. Analysis for sex effects in detection thresholds was completed with analysis of variance. The thresholds reported are the antilogs of the mean of the logged data.

Masking data was obtained by subtracting mean thresholds in water (Exp. 1) from mean thresholds in potato. Analysis of variance for sex effects in masking were completed on the logged threshold differences as once again the variance of the data appeared to be associated with the means. Spearman (ranked) correlations were generated within each cultural group between thresholds in water and thresholds in potato to examine the association between these measurements.

Hedonic data was analyzed with analysis of variance to determine if significant differences existed between the mean hedonic ratings of the four suprathreshold concentrations for each tastant. Multiple mean comparisons were carried out using Tukey's test. To compare threshold sensitivity and hedonic response, subjects were put into Hedonic Groups according to the concentration to which they assigned the highest hedonic score. Analysis of variance was then completed to detect differences between Hedonic Group thresholds.

RESULTS AND DISCUSSION

Detection Thresholds

Peruvian and Canadian detection thresholds for quinine sulphate and sodium chloride are found in Tables 4.1 and 4.2. A breakdown of thresholds by sex is also given. As the measurements were made in separate locales with different potato products, the thresholds will not be compared between the cultural groups. Peruvian thresholds for quinine sulphate and sodium chloride were 5.4 ppm and 217.0 ppm, respectively. Peruvian males detected quinine sulphate at a lower concentration than Peruvian females (4.3 ppm versus 8.1 ppm). Conversely, sodium chloride was detected at a lower concentration in females at 139.8 ppm compared to males at 281.5 ppm. The Canadian mean threshold for quinine sulphate was 8.9 ppm compared to 223.6 ppm for sodium chloride. Canadian females detected both quinine sulphate and sodium chloride at lower concentrations than Canadian males.

In both groups, the difference in the magnitude of sensitivity between bitterness and saltiness is apparent. Quinine sulphate was detected at concentrations of a magnitude of 5 to 12 ppm, compared to a magnitude of 140 to 390 ppm for sodium chloride. These values translate to a sensitivity to quinine sulphate that is about 30 times greater than sodium chloride.

Table 4.1 Peruvian bitter and salty detection thresholds in potato puree

	QUININE SULPHATE			SODIUM CHLORIDE		
	MEAN LOGn THRESHOLD (ppm)	STANDARD DEVIATION	MEAN THRESHOLD (ppm)	MEAN LOGn THRESHOLD (ppm)	STANDARD DEVIATION	MEAN THRESHOLD (ppm)
PERUVIANS (M + F)	1.69	0.92	5.42	5.38	0.74	217.02
PERUVIAN MALES	1.45	0.82	4.26	5.64	0.71	281.46
PERUVIAN FEMALES	2.09	1.02	8.08	4.94	0.62	139.77

Table 4.2 Canadian bitter and salty detection thresholds in potato puree

	QUININE SULPHATE			SODIUM CHLORIDE		
	MEAN LOGn THRESHOLD (ppm)	STANDARD DEVIATION	MEAN THRESHOLD (ppm)	MEAN LOGn THRESHOLD	STANDARD DEVIATION	MEAN THRESHOLD (ppm)
CANADIANS (M + F)	2.18	0.68	8.85	5.41	0.77	223.63
CANADIAN MALES	2.48	0.49	11.94	5.97	0.73	391.51
CANADIAN FEMALES	2.03	0.73	7.61	5.13	0.66	169.02

The trend identified in Chapter 3 for differences in sensitivity to these compounds in aqueous solution is also apparent when thresholds are measured in potato puree. As

The trend identified in Chapter 3 for differences in sensitivity to these compounds in aqueous solution is also apparent when thresholds are measured in potato puree. As hypothesized in Chapter 3, this trend may reflect an extraordinary human sensitivity to bitter tasting compounds. The trend may also be related to the affective quality of these tastes in potato. Salt is frequently added to potatoes by consumers due to its pleasantness, compared to bitterness which is the most commonly reported off-flavour in this food (Bennett and Hamilton, 1981; Sinden et al., 1976).

Threshold values for quinine sulphate in potato puree have not been reported previously. In terms of other bitter compounds however, Sinden et al. (1976) reported that potatoes with a glycoalkaloid content of 14mg/100g (140 ppm) were rated as "bitter" by a sensory panel. It appears from the present data that humans are able to detect bitter compounds at levels far below those at which they can recognize and identify the bitter taste.

For salt detection in potatoes, Bennett and Hamilton (1981) reported that panelists were able to distinguish potato samples adjusted to .05 M, 0.1 M, 0.2 M, and 0.5 M indicating that humans are quite sensitive to variations in salt content. Threshold values were not established.

Tables 4.3 and 4.4 contain analysis of variance statistics for the main effect of sex on detection thresholds for quinine sulphate and sodium chloride in potato puree. For both the Peruvian and the Canadian groups, there were significant sex effects for detection of sodium chloride but not for quinine sulphate. Tables 4.1 and 4.2 indicate that in both groups, females were clearly more sensitive to sodium chloride than males. A significant sex effect was also apparent in the analysis of sodium chloride thresholds in

Table 4.3 Peruvian analysis of variance mean squares and associated probabilities for detection thresholds in potato puree

	QUININE SULPHATE	SODIUM CHLORIDE
SEX	1.529 (0.189)	1.802 (0.069)
ERROR	0.802	0.463

Table 4.4 Canadian analysis of variance mean squares and associated probabilities for detection thresholds in potato puree

	QUININE SULPHATE	SODIUM CHLORIDE
SEX	0.686 (0.238)	2.307 (0.044)
ERROR	0.449	0.466

water (Chapter 3) at a probability level of 0.008 with no group*sex interaction. Lower thresholds for the primary tastes in women have been documented in the literature (Bertino et al, 1983; Doty, 1978). The presently reported results suggest that this effect exists cross-culturally and is not masked when thresholds are measured in a food product.

Masking Effects

Peruvian detection thresholds in aqueous solution and in potato are shown in Table 4.5 and are illustrated in Figure 4.1. Differences between the two thresholds are also given to indicate masking effects. For quinine sulphate, it is clear

Table 4.5 Mean Peruvian bitter and salty detection thresholds in aqueous solution and in potato puree

TASTANT	GROUP	MEAN THRESHOLD IN POTATO (ppm)	MEAN THRESHOLD IN WATER (ppm)	MASKING EFFECT[1]
QUININE SULPHATE				
	PERUVIANS	5.42	0.76	4.66
	PERUVIAN MALES	4.26	0.92	3.34
	PERUVIAN FEMALES	8.08	0.55	7.53
SODIUM CHLORIDE				
	PERUVIANS	217.02	107.77	109.25
	PERUVIAN MALES	281.46	141.17	140.29
	PERUVIAN FEMALES	139.77	68.72	71.05

1 mean threshold (potato) - mean threshold (water)

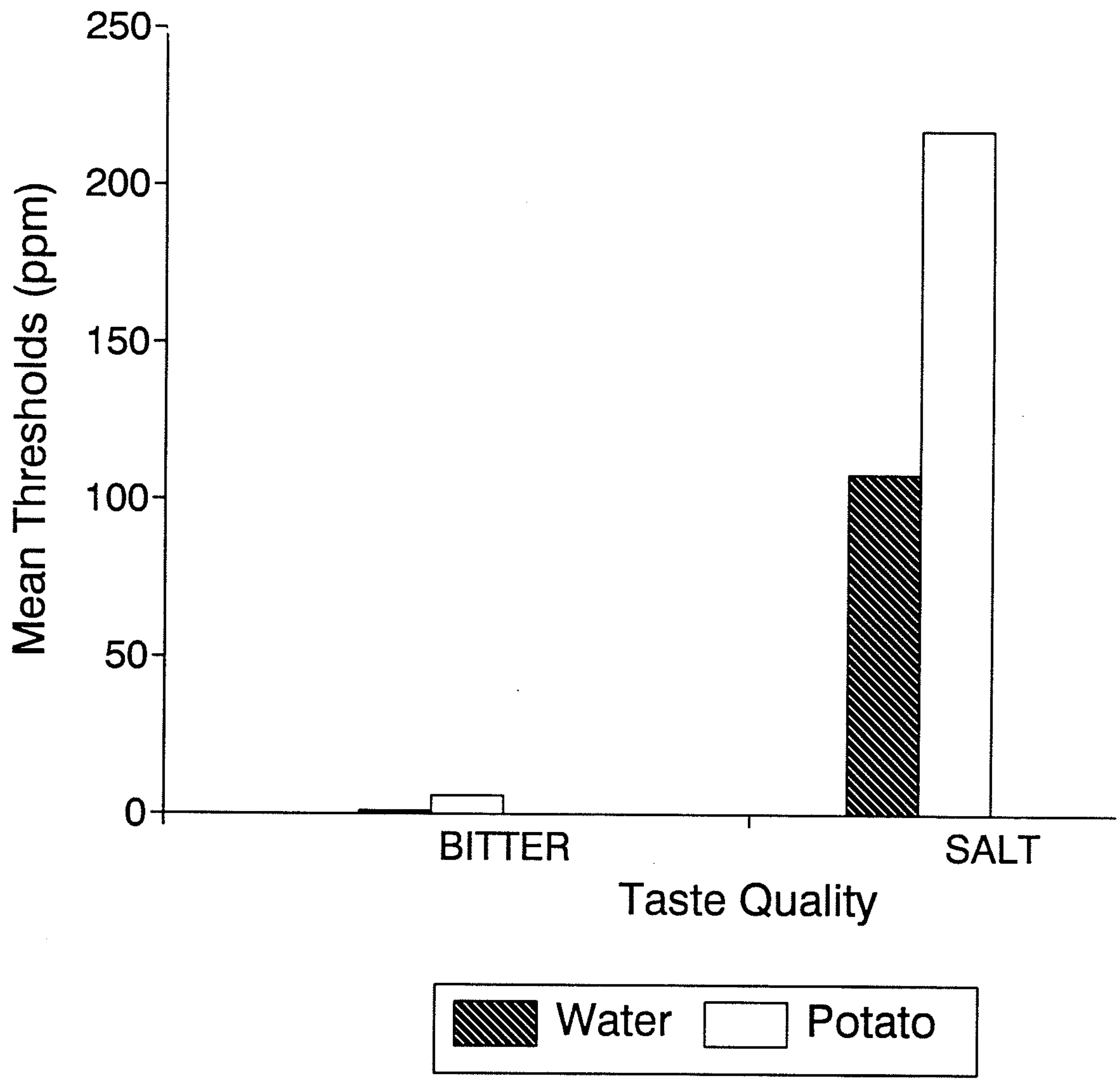

Figure 4.1 Masking Effects of Potato Puree on Detection Thresholds for Peruvians

that while detection thresholds were higher in potato than in water, the Peruvians were still remarkably sensitive to the bitter taste and were able to detect it at a mean concentration of 5.4 ppm. There appeared to be less masking of bitter detection thresholds in Peruvian males at a difference of only 3.3 ppm than in Peruvian females at 7.5 ppm. As mentioned previously however, sensitivities were reversed for sodium chloride masking. For males the masking effect was more than double that for females (140.3 ppm versus 71.0 ppm).

Similar effects were seen in the Canadian group with the Canadian potato product (Table 4.6, Figure 4.2). Again, the Canadian group was very sensitive to quinine sulphate in the puree with a mean detection threshold of 8.8 ppm and a masking effect of only 8.1 ppm. Similar to the Peruvians, detection thresholds were much higher for sodium chloride at 223.6 ppm with a masking effect of 150.7 ppm. The difference in masking for bitterness and saltiness which was observed in both cultural groups, again demonstrates the remarkable human sensitivity to the bitter taste. Mackey and Valassi (1956), after observing that the texture of foods affected perception of sweet, sour and salty tastants but not perception of bitter foods, hypothesized that the aftertaste associated with bitterness may allow for its perception regardless of texture. The sex effect observed in the Peruvian data for sodium chloride was also observed with the Canadian group. Again, Canadian females were more sensitive to sodium chloride in

Table 4.6 Mean Canadian bitter and salty detection thresholds in aqueous solution and in potato puree

TASTANT	GROUP	MEAN THRESHOLD IN POTATO (ppm)	MEAN THRESHOLD IN WATER (ppm)	MASKING EFFECT[1]
QUININE SULPHATE				
	CANADIANS	8.85	0.76	8.09
	CANADIAN MALES	11.94	0.83	11.11
	CANADIAN FEMALES	7.61	0.73	6.88
SODIUM CHLORIDE				
	CANADIANS	223.63	72.97	150.66
	CANADIAN MALES	391.51	126.47	265.04
	CANADIAN FEMALES	169.02	55.15	113.87

1 mean threshold (potato) - mean threshold (water)

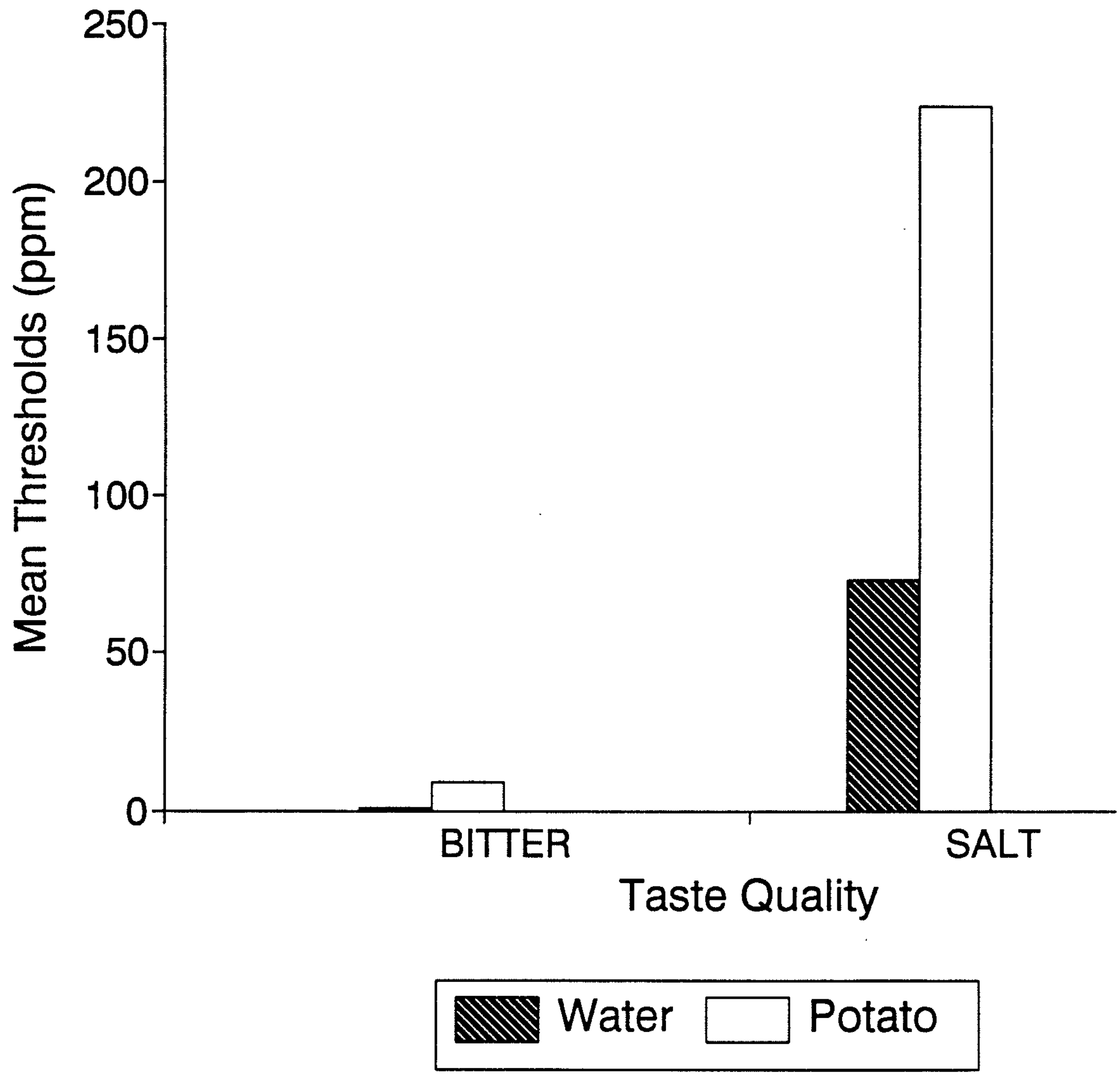

Figure 4.2 Masking Effects of Potato Puree on Detection Thresholds for Canadians

both water and in potatoes and masking effects were only half of those apparent in the Canadian males.

The masking ratios for Peruvians and Canadians are given in Table 4.7. These figures represent the ratio of the threshold in potato to the threshold in water for both cultural groups and the sexes within each group. Across the groups, there appeared to be similarity in masking despite the use of two different products. This consistency is particularly clear in the case of sodium chloride where the threshold in potato appears to be 2.0 times to 3.0 times the threshold in water regardless of sex. The ratios varied more for quinine sulphate, ranging from 7.1 for Peruvians and 11.6 for Canadians. While the masking effect in terms of ratios appears to be much higher in quinine sulphate, it is important to bear in mind that the concentrations were appreciably smaller in the case of quinine sulphate and a ten fold difference in thresholds only translated to a 10 ppm difference in concentration.

Analysis of variance was performed on the masking ratios to determine if there were significant sex effects within the groups. The results indicated that the only significant effect was for Peruvians for quinine sulphate ($p = 0.068$). This result is reflected in Table 4.7. For Peruvian males, the bitter threshold in potato was only 4.6 times the threshold in water compared to 14.7 times in females.

Table 4.7 Peruvian and Canadian masking ratios for bitter and salty detection thresholds in potato puree

GROUP	QUININE SULPHATE	SODIUM CHLORIDE
PERUVIANS (M+F)	7.13	2.01
PERUVIAN MALES	4.63	1.99
PERUVIAN FEMALES	14.69	2.03
CANADIANS (M+F)	11.64	3.06
CANADIAN MALES	14.38	3.10
CANADIAN FEMALES	10.42	3.06

Interestingly, for both groups, the sex effect apparent in detection thresholds for sodium chloride in potato and water was not reflected in the masking ratios. Peruvian males and females both possessed potato thresholds twice as high as those in water while both Canadian males and females possessed potato thresholds approximately 3.0 times those in water.

The masking of primary taste stimuli in food products has been documented in the literature, although the specific masking of potato has not been investigated. Guadagni et al. (1973) reported that limonin (bitter) threshold in orange juice was 6 times higher than that in water. Mackey and Valassi (1956) reported that caffeine thresholds were .0011 M in foods (tomato juice and custard) compared to .000485 M in water (2.3 times higher in food) , and that sodium chloride thresholds rose to .0052 M in foods from .0012 M in water (4.3 times higher in food). The authors also stated that texture will have an effect on the perceptibility of tastants, with detection easiest in a liquid, followed by a foam, followed by a gel.

Several factors may contribute to the masking effect observed with the potatoes. Masking may result from lack of contact of the tastant with the taste receptors. This lack of contact may be due to binding of the water in which the tastant is dispersed by the potato flakes, thereby reducing the availability of the tastants to the receptors. Masking could also be due to a lack of adequate time for the tastants to reach and bind with the receptors before the potato is swallowed. The textural effects proposed by Mackey and Valassi (1956) are probably significant with regards to potato as the texture is semi-solid and thick. A physiological explanation for the masking would include reduced perceptibility of the tastants due to other information regarding texture and other tastes entering the sensory system and somehow weakening the message sent from the receptors. This idea was forwarded by Lawless and Stevens (1984) as a possible factor in the reduced perceptibility of tastants when consumed with chemical irritants such as capsicum.

It should be noted that the differences in masking observed for bitter and salty tastants in potato could change given an alternate food product. Mackey and Valassi (1956) stated that regardless of texture, sodium chloride, sucrose and caffeine were easier to detect in custard, while tartaric acid was easier to detect in tomato juice. Given the observation that dehydrated potato lacks intense potato flavour (Sapers, 1975), the results reported presently may underestimate the masking effect of fresh potato.

Comparability of Thresholds in Potato and Water

Spearman (ranked) correlations for thresholds in potato and in water are given in Table 4.8. No significant correlations were observed for quinine sulphate and sodium chloride in either the Peruvian or the Canadian group. This result lends support to the suggestion that thresholds in water cannot predict gustatory response in food systems (Bartoshuk, 1978; Pangborn and Pecore, 1982; Mattes, 1985). Factors such as familiarity of the subject with the food of interest or motivation may contribute to this lack of an association. The results have important implications for sensory research. Screening of panelists for evaluation of food should be conducted using the product to be evaluated, and not using aqueous solution alone.

Hedonic Response

Peruvian and Canadian hedonic response to supra-threshold concentrations of quinine sulphate and sodium chloride are given in Tables 4.9 and 4.10. Judgments were made using a 9 point hedonic scale. Peruvians rated all concentrations of quinine sulphate lower than all concentrations of salt. For

Table 4.8 Spearman correlations for bitter and salty detection thresholds in aqueous solution and potato puree

	QUININE SULPHATE	SODIUM CHLORIDE
PERUVIANS	0.386 (0.140)[1]	0.015 (0.956)
CANADIANS	0.269 (0.331)	0.181 (0.517)

1 associated probabilities

Table 4.9 Peruvian mean hedonic ratings of suprathreshold concentration of bitter and salty tastants in potato puree

TASTANT	CONCENTRATION (ppm)	MEAN HEDONIC SCORE[1,2]
QUININE SULPHATE		
	9	3.73 a
	13	3.53 ab
	20	2.87 b
	30	1.87 c
SODIUM CHLORIDE		
	298	5.20 a
	596	5.67 a
	1191	5.73 a
	2383	7.20 b

1 scored with a hedonic scale where 1 = dislike extremely and 9 = like extremely
2 means with the same letter are not significantly different

Table 4.10 Canadian mean hedonic ratings of suprathreshold concentrations of bitter and salty tastants in potato puree

TASTANT	CONCENTRATION (ppm)	MEAN HEDONIC SCORE[1,2]
QUININE SULPHATE		
	9	5.13 a
	13	4.20 ab
	20	3.47 bc
	30	2.67 c
SODIUM CHLORIDE		
	293	5.33 a
	586	5.87 a
	1171	5.87 a
	2343	5.87 a

1 scored with a hedonic scale where 1 = dislike extremely and 9 = like extremely
2 means with the same letter are not significantly different

quinine sulphate, increasing concentrations were rated decreasingly from 3.73 to 1.87. Conversely, increasing concentrations of sodium chloride were rated increasingly from 5.20 to 7.20. Similarly, Canadians rated all concentrations of quinine sulphate lower than all concentrations of sodium chloride. Again, increasing concentrations of quinine sulphate were judged as being increasingly disliked. For sodium chloride however, there was not a significant difference in the hedonic means for the different concentrations.

Multiple comparisons of means by Tukey's Test suggested that Peruvians and Canadians were better able to differentiate between concentrations of quinine sulphate than sodium chloride. These results, as well as the trends indicated above, reflect the observation that bitter is considered to be an off-flavour in potatoes whereas the flavour of salt is expected and is deemed pleasant (Sinden et al. 1976; Bennett and Hamilton, 1981).

Threshold Sensitivity and Hedonic Response

To compare threshold sensitivity and hedonic response to supra-threshold concentrations of quinine sulphate and sodium chloride, subjects were grouped according to their most preferred concentration. The mean thresholds of the groups were then compared. Analysis of variance indicated that there were no significant differences in the means of the groups. This result supports those reported by Pangborn and Pecore (1982), Druz and Baldwin (1982) and Mattes (1985) who also failed to show a correlation between thresholds and hedonic response. Factors such as race, age, sex, religion, education, socio-economics, psychological and physiological inputs may outweigh acuity in determining pleasantness and preference ratings (Amerine et al., 1965).

GENERAL DISCUSSION

This study is unique in the measurement of thresholds for quinine sulphate and sodium chloride in potato. It is also important in its preliminary examination of the comparability of taste response in aqueous solution and in a food product in cross-cultural studies.

Comparison of threshold values in water and in potato reveals important similarities and differences. It is interesting to note that human thresholds for the bitter taste are remarkably low in both aqueous solution and in potato. Both the Peruvian and Canadian subjects were able to detect quinine sulphate at a level of 5 to 10 ppm, compared to sodium chloride which was detectable at 150 to 400 ppm. Again, this heightened sensitivity may reflect a protective function against bitter toxins (Guyton, 1976). Another trend apparent in both water and potato were the sex effects for detection thresholds for sodium chloride. In both cultures, females were more sensitive than males. This gender difference in thresholds has been well documented in the literature, although differences have been reported for all the primary tastes and not saltiness in particular (Doty, 1978). Doty (1978) proposed a number of different mechanisms that may be responsible for this relationship including a sampling bias in terms of a non-random selection of males and females, differences in the frequencies of certain habits which may affect sensitivity (e.g. smoking or dieting), physiological differences related to taste, and differences between the sexes in response bias to the experimental situation (e.g. differences in responsiveness to a female experimenter). As the sex differences were documented in only two of the tastes in the water tests and in only one taste in the potato tests, psychological and sampling effects probably were not primarily responsible for the observed gender differences. Physiological differences which may affect the ability of salt to reach and bind with the receptors such as salivary ions, thickness and flow may exist between the sexes (Doty, 1978). The question warrants further study.

Important differences were observed between thresholds in water and potato. The relative masking of bitter and salty tastants in potato was shown to differ, but was remarkably similar in the two cultural groups given the fact that different potato products were used. The ratios of masking indicated that potato salt thresholds are approximately two times water thresholds in Peruvians and Canadians (males and females) while potato quinine sulphate thresholds are between 5 and 10 times those in water. It must be reiterated however, that a 10 fold difference in quinine sulphate ratio only translates to a concentration difference of about 10 ppm. It is important to mention that this differential in masking between bitterness and saltiness may only be applicable to potatoes as bitterness is deemed unpleasant and saltiness pleasant in this food (Sinden et al.,1976; Bennett and

Hamilton, 1981). Expected flavours in food products may affect sensitivity and these ratios could conceivably change if thresholds were measured in a product such as coffee where bitterness is expected, but saltiness is not. It is also possible that the threshold values are only specific to instant mashed potato. Dehydrated potato products have been shown to lack typical potato flavour due primarily to the loss of volatiles during dehydration (Sapers, 1975). Detection thresholds and masking values reported may underestimate those encountered in fresh potatoes.

The lack of correlation between threshold scores in water and potato indicates that the most sensitive individuals in water were not the most sensitive individuals in potato. The lack of an association between taste response in water and foods has been well documented (Bertino et al., 1983; Mattes, 1985; Pangborn and Pecore, 1982). This difference may be due to such factors as individual differences in motivation, training or familiarity with potato puree. The results have important implications for the acquisition of panelists for sensory evaluation in that all screening for sensitivity should be completed with the product of interest rather than in water.

The lack of correlation between threshold sensitivity and hedonic response was also important and is supported in the literature (Druz and Baldwin, 1982; Mattes, 1985). It is clear that any cross-cultural comparison of suitability of panelists should include measures of threshold sensitivity, suprathreshold intensity perception and hedonic response to give a reflection of the full taste dynamic. These measures appear to give different information and a taste profile incorporating all these measures similar to that suggested by Mattes (1985) may be most appropriate for cross-cultural studies.

For the Andean crops sensory research, although the potato data cannot be compared directly, it appears that sensitivity to quinine sulphate and sodium chloride was similar in Canadians and Peruvians. While the values for bitterness cannot directly predict sensitivity to glycoalkaloids, it appears that Canadians display ample sensitivity to this taste. Zitnak and Filadelfi (1985) reported that glycoalkaloids are 4 times more bitter than caffeine. Similarly, Guyton (1976) reported that if quinine had a bitter index of 1, caffeine possesses a bitter index of 0.4, that is quinine is about 2.5 times more bitter than caffeine. It may be hypothesized therefore, that glycoalkaloids may be about 1.5 to 2 times more bitter than quinine. Glycoalkaloids are believed to be toxic at a level of 20mg/100g fresh weight potatoes (200 ppm) (Jadhav et al., 1981). Canadians and Peruvians possessed quinine sulphate detection thresholds of 7 to 13 ppm in potato. If glycoalkaloids are 2 times more bitter than quinine, theoretically glycoalkaloids might be detected at a level of

3.5 to 6.5 ppm. Both Canadians and Peruvians would be able to detect the bitterness of glycoalkaloids in potato at levels well below those considered toxic (200 ppm). A carefully controlled comparison of Canadian and Peruvian glycoalkaloid thresholds in potato would test the validity of this hypothesis.

The demonstrated sex effects on detection thresholds suggest that panels should be carefully balanced in terms of sex such that the range of sensitivities expected in the target consumer population is represented. Although hedonic response could not be directly compared in the two cultural groups due to the use of different potato products, the results suggested that Peruvians may better distinguish between varying concentrations of sodium chloride than Canadians. A direct cross-cultural study of hedonic response and suprathreshold scaling using the same potato product is warranted.

CONCLUSIONS

Although the potato threshold data cannot be compared directly, Peruvians and Canadians demonstrated similar trends in sensitivity to quinine sulphate and sodium chloride. The potato data indicated that humans are remarkably sensitive to bitterness in this food system. Both Canadians and Peruvians were able to detect the bitter taste at levels far below those hypothesized to be toxic. The trend of women being more sensitive to sodium chloride than men was present in both cultural groups and in both potato puree and aqueous systems.

Although Peruvian and Canadian hedonic data could not be compared directly, both groups preferred increasing concentrations of sodium chloride in the range studied and decreasing concentrations of quinine sulphate. The data indicate that in both cultures salt is deemed pleasant in potato, while bitterness is deemed unpleasant. The hedonic data suggested that Canadian preferences for sodium chloride did not differ at the concentrations tested and a preference breakpoint may have been reached. Alternatively, Peruvians may better differentiate suprathreshold concentrations of sodium chloride than Canadians. Further hedonic testing is required to clarify the results.

The data have several implications for Andean foods sensory research. Firstly, similarity in bitter and salt thresholds in Canadians and Peruvians suggest that Canadians display ample sensitivity to bitterness and would be able to detect it in potatoes. Secondly, hedonic trends appear to be similar in the two groups suggesting that Canadians may also be able to predict pleasantness on a preliminary level. The possibility that Peruvians differentiate suprathreshold concentrations of sodium chloride more effectively than Canadians should be studied with tests of intensity scaling in the same potato product. The sex effects for detection thresholds in both groups suggest that sensory panels should be matched for sex. The lack of correlation between detection thresholds in water and in potatoes implies that screening for potato panels should include tests using potatoes as the carrier system.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

Results of the cross-cultural comparison of taste thresholds in Peruvians and Canadians indicated that sensitivity is similar in the two groups for bitterness and saltiness. These similarities were observed in both aqueous solution and potato puree and included similar masking effects. Differences were reported in sweet and sour sensitivity in aqueous solution. Sex effects for salt detection thresholds were evident in both systems and both groups. Similar trends in hedonic response to quinine sulphate and sodium chloride in potato were observed in Canadians and Peruvians. Both groups preferred increasing concentrations of sodium chloride and decreasing concentrations of quinine sulphate. Unfortunately possible confounding factors such as the use of different water and different potato products in the two locales prevents the evidence from being conclusive.

The results have important implications for the conduct of future cross-cultural research. Although mean Peruvian and Canadian thresholds in potato were similar, correlations between individual threshold sensitivity in water and potatoes were not significant within the cultural groups. This data suggests that examination of cross-cultural differences only in aqueous solution may miss differences existing when tastants are presented in foods as suggested by Bertino et al. (1983). These carrier-dependent differences may be shown to exist if the food under study is more common in one culture than the other. Potatoes are present in both the Canadian and Peruvian diets possibly explaining the similarity in mean sensitivity to the tastants in this food. It is clear that cross-cultural studies should include measurement of gustatory response in food systems.

Threshold sensitivity was also not correlated with hedonic response. This lack of an association has been well documented in the literature (Mattes, 1985; Druz and Baldwin, 1982). Mattes (1985) hypothesized that thresholds, supra-threshold response and hedonic response are unrelated. The present data support this hypothesis and indicate that all three measures should be included in cross-cultural descriptions of gustatory response. Finally, the results presented in Exp.1 offer an alternative method for measuring the effect of diet on cross-cultural differences in taste sensitivity. The difficulty in formulating equally valid dietary instruments for different cultures may be circumvented by the identification of foods representing the four basic tastes present in both cultures (e.g. lemons, vinegar, chocolate, salted nuts, coffee). Frequency of intake of these foods can then be directly compared.

Individuals attempting cross-cultural research should be aware of the difficulties likely to be encountered in experiment control due to unavailability of laboratory equipment and supplies in some locales. The possible effects of environmental factors such as different ambient temperatures and different sensory booth conditions (e.g. degree of privacy and lighting) should be recognized and controlled as carefully as possible. Results of cross-cultural studies should always be interpreted with these factors in mind.

The results of the present cross-cultural study warrant further comment. Threshold values determined in solution were below those reported previously suggesting that the methods used were highly sensitive. The triangle method of threshold testing has been shown to be particularly sensitive (McBride and Laing, 1979) and is recommended for use when high measurement sensitivity is required. This method also avoids problems associated with semantics which is particularly important in cross-cultural studies. The degree of training for individual panelists should be monitored however, so that accurate concentration scales are maintained throughout testing. It should also be noted that the method is cumbersome and requires a large quantity of sample, probably excluding its use in field conditions.

The data presented also have interesting implications for the Andean foods sensory research. In terms of threshold sensitivity, Canadians appear to possess similar sensitivity as Peruvians to bitterness and would hypothetically be able to detect glycoalkaloids at levels well below those considered to be toxic. Although the threshold values for the potato puree may underestimate those for fresh potato, the values may be comparable to chuno which is also dehydrated and lacks fresh potato flavour. Chuno has been shown to contain glycoalkaloid levels of approximately 5mg/100g (50 ppm) (Werge, 1978). Canadians and Peruvians can be expected to be equally sensitive to bitterness at these levels.

The lack of a difference in bitter thresholds between the two cultural groups was not surprising given the urban nature of the populations tested. Examination of the diets in the groups suggested that intake of bitter foods was not different. A study comparing bitter taste response in urban Peruvian and Canadian groups with rural Peruvian groups processing chuno might show differences and should be undertaken to ensure that urban panelists are able to judge foods for a rural market.

The ability of Canadians to evaluate pleasantness and suprathreshold intensity of tastants in potato products requires further study. The hedonic data suggested that Canadians and Peruvians display similar trends in rating the pleasantness of quinine sulphate and sodium chloride in potato but that there may be a discrepancy in ability to discriminate suprathreshold concentrations of tastants. Again, a cross-cultural study examining thresholds, suprathreshold response and hedonic response in the same potato product (e.g. chuno) in Canadians and urban and rural Peruvians is warranted.

It appears therefore, that the use of Canadian panelists for the detection of glycoalkaloids in bitter potatoes and chuno may be feasible. Further study may also show that Canadians could complete preliminary assessment of the acceptability of these foods. The data presented indicate that experimenters recruiting panelists for the sensory evaluation of these foods should conduct screening using the product to be judged by the panel rather than water. Panels should also be balanced in terms of sex to compensate for gender differences in taste perception.

CHAPTER 6

IMPLICATIONS FOR FURTHER RESEARCH

1. A cross-cultural study examining comparability of gustatory response in Canadians and urban and rural Peruvians in potatoes and chuno should be completed. The measurements should include threshold, supra-threshold discrimination and hedonic response testing with a focus on the bitterness of glycoalkaloids.

2. The data presented suggest that Canadian panelists will be able to detect glycoalkaloids in the range expected in chuno.

3. Experimenters recruiting individuals for Andean foods sensory research should keep panels balanced in terms of sex. Screening of panelists should be completed with the food (potatoes or chuno) to be evaluated by the panel.

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APPENDICES

Appendix 1

CANADIAN BALLOT FOR THRESHOLDS IN AQUEOUS SOLUTION

Name ______________________ Date ______________

Instructions: You have been given 6 sets of samples for evaluation. In each set, two of the samples are identical and one is different. Taste the samples in the order indicated and identify the odd sample. Do not swallow the samples and rinse with the water provided before proceeding to the next set of samples.

1. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

2. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

3. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

4. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

5. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

6. Code ____ ____ ____ Check odd sample ____________ ____________ ____________

In the last group of samples, what was the taste of the odd sample?

sour______ sweet______ bitter_______ salty______

Appendix 2

PERUVIAN BALLOT FOR THRESHOLDS IN AQUEOUS SOLUTION

Nombre:____________________________ Fecha:______________

Instrucciones: Ud. tiene 6 grupos de muestras para evaluar. En cada grupo, 2 de la muestras son ídenticas y 1 es diferente. Guste Ud. las muestras en el orden indicado e identifique la muestra diferente. No trague las muestras. Enjuage con agua antes de gustar el próximo grupo de muestras.

1. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

2. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

3. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

4. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

5. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

6. Código ______ ______ ______ identifique la muestra diferente ________________________ ________________________ ________________________

¿En el último grupo de muestras, cuál fue el sabor de la muestra diferente?
ácido_____ dulce_____ amargo_____ salado_____

Appendix 3

CANADIAN FOOD FREQUENCY QUESTIONNAIRE

Please indicate how often you eat or drink the following foods and beverages. Use whichever column is most appropriate for each item, but be sure to use only one space for each food. If, for example, you eat corn about twice a week, rice about 5 times a month and milk 3 times a day you would fill in the chart as follows:

	Number of times per day	Number of times per week	Number of times per month	Less than once a month
Example:				
corn		**2**		
rice			**5**	
milk	**3**			
cake				
doughnuts				
oranges				
orange juice				
peanuts				
cookies				
candy				
chocolate				
ham				
beer				
lemon				
grapefruit				
grapefruit juice				
coffee				
tea				
dill pickles				
pretzels				
potato chips				

	Number of times per day	Number of times per week	Number of times per month	Less than once a month
vinegar				
sour cream				
pie				
red wine				
white wine				
lemonade				
pudding				
breakfast cereal				
raisins				
ice cream				
salami				
pizza				
tonic water				
chocolate milk				
tomatoes				
processed cheese				
yogurt				
apples				
soft drinks				
green olives				
bacon				
coca-cola				
soya sauce				

Appendix 4

PERUVIAN FOOD FREQUENCY QUESTIONNAIRE

Por favor, indique la frecuencia con que Ud. come o bebe los alimentos y bebidas que se proponen. Utilize cualquier columna la más apropiada por cada cosa, pero asegurarse de usar solo un espacio por cada alimento. Si, por ejemplo, Ud. come maiz dos veces por semana, arroz cinco veces por mes y leche tres veces al día, completería el cuadro como sigue:

	NUMERO DE VECES POR DIA	NUMERO DE VECES POR SEMANA	NUMERO DE VECES POR MES	MENOS QUE UNA VEZ POR MES
ejemplo:				
Maiz		2		
Arroz			5	
Leche	3			
Torta (cake)				
Galletas dulces (cookies)				
Pasteles (pastry)				
Caramelos (candy)				
Naranjas (oranges)				
Jugo de naranja (orange juice)				
Ceviche (raw fish in lemon)				
Uvas (grapes)				
Piña (pineapple)				
Chocolate				
Vino dulce (sweet wine)				
Vino seco (dry or red wine)				
Leche condensada (condensed milk)				

	NUMERO DE VECES POR DIA	NUMERO DE VECES POR SEMANA	NUMERO DE VECES POR MES	MENOS QUE UNA VEZ POR MES
Cerveza (beer)				
Café (coffee)				
Té (tea)				
Gaseosas (soft drinks)				
Coca-cola				
Maiz tostada (toasted corn)				
Maní (peanuts)				
Papas fritas (french fries)				
Habas saladas (salted faba beans)				
Chizitos (Cheesies)				
Mermelada (jam)				
Miel (honey)				
Ciruelas (cherries)				
Plátanos (bananas)				
Jamón (ham)				
Salchichas (sausages)				
Pizza				
Queso (cheese)				
Tocino (bacon)				
Aceitunas (olives)				
Chupe (stew)				

	NUMERO DE VECES POR DIA	NUMERO DE VECES POR SEMANA	NUMERO DE VECES POR MES	MENOS QUE UNA VEZ POR MES
Chicharrón (salted pork fat)				
Cocoa				
Ají (chili pepper)				
Ocopa (hot sauce)				
Rocoto (hot pepper)				
Pimienta picante (black pepper)				
Limón (lemon)				
Vinagre (vinegar)				
Sillau (soya sauce)				
Helados (ice cream)				
Manjar (sweet icing)				
Gelatina (jello)				
Mazamorra (sweet dessert)				
Tomate (tomato)				
Yogurt				
Limonada (lemonade)				
Chicles (chewing gum)				
Chuño				
Quinoa				
Tarwi				

Appendix 5

LIST OF INGREDIENTS FOR INSTANT POTATO PUREE IN PERU AND CANADA

Peru:

Knorr's Potato Puree

potatoes
antioxidants (unspecified)
stabilizers (unspecified)

Canada:

Carnation Real Potato Flakes

potatoes
glycerol monostearate
sodium acid pyrophosphate
sodium metabisulphite
calcium stearoyl-2-lactylate
B.H.T.
B.H.A.

Appendix 6

CANADIAN BALLOT FOR THRESHOLDS IN POTATO PUREE

Name____________________________ Date_______________

Instructions: You have been given 6 sets of samples for evaluation. In each set, 2 of the samples are identical and 1 is different. Taste the samples in the order indicated and identify the odd sample. Rinse with the water provided after tasting each sample.

1. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

2. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

3. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

4. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

5. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

6. Code ________ ________ ________ Check odd sample ______________ ______________ ______________

Appendix 7

PERUVIAN BALLOT FOR THRESHOLDS IN POTATO PUREE

Nombre:__________________________ Fecha:______________

Instrucciones: Ud. tiene 6 grupos de muestras para evaluar. En cada grupo, 2 de la muestras son ídenticas y 1 es diferente. Guste Ud. las muestras en el orden indicado e identifique la muestra diferente. Enjuage con agua antes de gustar la próxima muestra.

1. Código — identifique la muestra diferente

2. Código — identifique la muestra diferente

3. Código — identifique la muestra diferente

4. Código — identifique la muestra diferente

5. Código — identifique la muestra diferente

6. Código — identifique la muestra diferente

Comentarios:

Appendix 8

CANADIAN BALLOT FOR HEDONIC TESTING

Name:________________________ Date:________________

Instructions: You have been given 4 samples to evaluate. Taste them in order from left to right as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase under the sample code number.

Code______	Code______	Code______	Code______
______ Like Extremely	______ Like Extremely	______ Like Extremely	______ Like Extremely
______ Like Very Much	______ Like Very Much	______ Like Very Much	______ Like Very Much
______ Like Moderately	______ Like Moderately	______ Like Moderately	______ Like Moderately
______ Like Slightly	______ Like Slightly	______ Like Slightly	______ Like Slightly
______ Neither Like Nor Dislike	______ Neither Like Nor Dislike	______ Neither Like Nor Dislike	______ Neither Like Nor Dislike
______ Dislike Slightly	______ Dislike Slightly	______ Dislike Slightly	______ Dislike Slightly
______ Dislike Moderately	______ Dislike Moderately	______ Dislike Moderately	______ Dislike Moderately
______ Dislike Very Much	______ Dislike Very Much	______ Dislike Very Much	______ Dislike Very Much
______ Dislike Extremely	______ Dislike Extremely	______ Dislike Extremely	______ Dislike Extremely

Comments:

Appendix 9

PERUVIAN BALLOT FOR HEDONIC TESTING

Nombre:________________________ Fecha:________________

Instrucciones: Usted tiene 4 muestras para evaluar. Pruebelas en el orden indicado e indique cuanto le gustan o disgustan, chequeando la descripción que usted considere más apropiada en cada escala.

Código_______	Código_______	Código_______	Código_______
Me gusta muchí-simo _______	Me gusta muchí-simo _______	Me gusta muchí-simo _______	Me gusta muchí-simo _______
Me gusta mucho _______	Me gusta mucho _______	Me gusta Mucho _______	Me gusta mucho _______
Me gusta moderada-mente _______	Me gusta moderada-mente _______	Me gusta moderada-mente _______	Me gusta moderada-mente _______
Me gusta ligera-mente _______	Me gusta ligera-mente _______	Me gusta ligera-mente _______	Me gusta ligera-mente _______
No me gusta ni me dis-gusta _______	No me gusta ni me dis-gusta _______	No me gusta ni me dis-gusta _______	No me gusta ni me dis-gusta _______
Me disgusta ligera-mente _______	Me disgusta ligera-mente _______	Me disgusta ligera-mente _______	Me disgusta ligera-mente _______
Me disgusta moderada-mente _______	Me disgusta moderada-mente _______	Me disgusta moderada-mente _______	Me disgusta moderada-mente _______
Me disgusta mucho _______	Me disgusta mucho _______	Me disgusta mucho _______	Me disgusta mucho _______
Me disgusta muchí-simo _______	Me disgusta muchí-simo _______	Me disgusta muchí-simo _______	Me disgusta muchí-simo _______

Comentarios:

Appendix 10

SAMPLE CONVERSION OF THRESHOLD CONCENTRATION FROM MOLARITY TO PPM

Potato Puree Weight (Canada)

250 mL water	250 g	
125 mL milk	129 g	(Health and Welfare Canada, 1987)
70 g potato	70 g	

= 449 g potato puree

Sodium Chloride

.048 M = 0.70128 g in 250 mL water

= .70128 g NaCl in 449 g potato puree

Conversion to ppm

$$\frac{.70128 \text{ g}}{449 \text{ g}} = \frac{X}{1{,}000{,}000 \text{ g}}$$

= 1561.8708 ppm