Application of Near Infrared Spectroscopy (NIR) for Monitoring the Quality of Milk, Cheese, Meat and Fish - Review -

Y. J. Ru* and P. C. Glatz
Pig and Poultry Production Institute, South Australian Research and Development Institute
Roseworthy, South Australia, Australia 5371

ABSTRACT : The traditional methods for determining the quality of milk, cheese and meat are tedious and expensive, with a significant wastage of chemicals which pollute the environment. To overcome these disadvantages, the potential of near infrared spectrophotometry (NIR) for monitoring the quality of milk and meat has been evaluated by a number of researchers. While most studies indicate that NIR can be used to predict chemical composition of milk and meat, and to monitor the cutting-point during cheese manufacturing, one study demonstrated the potential of NIR to predict sensory characteristics (e.g. hardness and tenderness) of beef. These calibrations were developed on a small number of samples, limiting their value for adoption by the industries. Now that the sophisticated computer software is available, more robust calibrations need to be developed to monitor both chemical and physical characteristics of meat and meat products simultaneously. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 7 : 1017-1025)*

Key Words : NIR Application, Meat Quality, Dairy Products

INTRODUCTION

Determining the major nutritional composition of foodstuffs using classic analytical methods is slow and expensive. These procedures often require the use of chemical reagents and the test samples need to be pre-processed (e.g. grounding) before analysing. The consequence of these traditional methods is the accumulation of chemical wastage and the contamination of environment. To overcome the disadvantages of the traditional methods, near infrared spectroscopy (NIR) has been used for rapid analyses of nutritional components of foodstuffs (Rodriguez Otero et al., 1995; Osborne et al., 1993). It has already been demonstrated that NIR analysis of foodstuffs is simple and accurate. After NIR analysis samples are not destroyed, which is particularly valuable for seeds used in plant breeding programs (Ronalds and Miskelly, 1985), or when monitoring stages in food processing (Kaffka and Gyarmati, 1995).

To date, a number of NIR calibrations have been developed for the analyses of protein, oil and moisture content of agricultural commodities, and chemical composition and nutritive value of feed for ruminants and monogastrics (Flinn et al., 1987; Wu, 1995). The principle and progress of NIR application in these areas have been reviewed in detail by Givens et al. (1997) and Osborne (1981). This review will only focus on the NIR application for monitoring the quality of dairy products, meat and fish products.

* Address reprint request to Y. J. Ru. E-mail: Ru.Yingjun@saugov.sa.gov.au.

DAIRY PRODUCTS

Milk

Since the first NIR measurement of milk and milk product constituent was reported by Goulden (1957), the application of NIR technology has been studied extensively (Casado et al., 1978; Baer, 1983; Woollard et al., 1985; Frankhuizen et al., 1985). A number of calibrations have been developed for predicting nutritional components of raw milk, powdered milk, cheese and butter (table 1), although these calibrations are based on a limited number of samples. Recent research has shown that the content of fat, protein, lactose and solids non-fat in raw milk can be predicted with an R value over 0.9 (Tsenkova et al., 1994; Tsenkova, 1995). The content of fat, protein, water and ash in dry milk can be estimated more accurately than in fresh milk. Schmilovitch et al. (1992) also reported a correlation coefficient of 0.80-0.90 for predicting the content of fat, protein and lactose in milk. These results indicate that NIR technology has potential for on-line real time analysis of the composition of fresh milk (Schmilovitch et al., 1992) and milk products (Asimopoulos and Pope, 1994) even though Ronalds and Miskelly (1985) suggested that NIR is not superior to the existing methods for analysing liquid milk.

The accuracy of NIR prediction for milk component is influenced by a number of factors. Water content in fresh milk is one of the major contributors to the variation in the NIR spectra even though the liquid milk samples were analysed successfully using Foss Infrared spectrometers (Parker,

Table 1. Correlation coefficients, standard error of calibration (SEC) and standard error of performance (SEP) for prediction of chemical composition of dairy products using near infrared (NIR) spectrophotometry

Product	Source	Component	Correlation coefficient	SEP	SEC	No. of samples
Raw milk	Tsenkova et al. (1994); Tsenkova et al. (1995)	Fat	0.99		0.55	200
		Protein	0.99		0.15	200
		Lactose	0.95-0.99		0.12	200
		Solids non fat	0.95-0.99		0.15	200
	Hall and Chan (1994)	Fat	-0.99	0.04	0.04	
		Protein	0.95	0.08	0.08	
		Lactose	0.82	0.04	0.05	
Milk	Hall and de Thomas (1994)	Fat	0.92		0.07	40
Powdered milk	Barabassy and Kaffka (1995)	Fat	0.98-0.99		0.13	104
		Protein	0.91-1.00		1.89-4.27	104
		Lactose	0.99-1.00		1.88-6.79	104
		Water	0.99-1.00		0.10-0.16	104
		Ash	0.99	0.099	0.18-0.26	104
Nonfat dry milk	Baer et al. (1983); Baer (1983)	Fat	0.96	0.438	0.08	82
		Protein	0.91	0.594	0.25	82
		Lactose	0.89	0.274	0.48	82
		Water	0.97		0.22	82
Cheese	Hall et al. (1994)	Fat	-0.96		0.17	34
		Moisture	-0.98		0.23	29
	Rodriguez Otero et al. (1995)	Fat	0.99		0.39	92
		Protein	0.99		0.40	92
		Total solids	0.99		0.41	92
Butter	Hall et al. (1994)	Moisture	-0.86		0.10	100

1995). It has been noted that water absorbs strongly in the NIR region and it can create a significant background problem in quantitative analysis, particularly for minor constituents (Hall and Chan, 1994).

Fat content in the milk samples also affects the NIR spectra, consequently the accuracy of predicting other components such as protein. Hall and Chan (1994) reported that the baseline of the absorbance spectra increased with increasing fat concentration and the absorbance of oil at 2306 nm affected the absorbance of protein at 2170 nm. As the number of particles (fat globules) increase, the amount of radiation transmitted through the sample decreases and the effective path-length of the radiation through the sample increases. To minimise these effects and maintain sensitivity to the components of interest, a very short optical path-length can be used, and the absorbance maxima need to be converted to minma surrounded by positive side-lobes. This mathematical treatment reduces baseline offsets and enhances spectral features without degrading signal-to-noise response. Kamishikiryo Yamashita et al. (1994) also demonstrated that the correction of the prediction equations using casein solutions containing 0-4% oil significantly improved the determination of protein content in commercial milk containing 2-5% fat, with a correlation coefficient of 0.89.

Sample preparation is often seen as a factor influencing the NIR spectra. Some products may require further processing to achieve uniform particle size (Ronalds and Miskelly, 1985). However, it was proven that the determination of fat, protein and lactose in unhomogenised milk using NIR meets the current official analytical performance requirements (Hall and Chan, 1994).

Except for the influence of chemical composition of milk per se, health status of cows, preservatives and other foreign substances have a strong impact on NIR spectra of milk. Early work showed that the NIR spectra for milk was influenced by mastitis which can be diagnosed by NIR with an accuracy of 95% (Tsenkova et al., 1994). A bias adjustment is also necessary when testing preserved milk due to the variable effect of addition of preservative (e.g. potassium dichromate) on chemical composition of milk during the storage (Black et al., 1985). For example, the addition of NaCl can induce a shift of water absorption bands at 1450 and 1940 nm even though temperature is the most important factor

affecting spectra (Pedretti et al., 1993).

Cheese

Although using NIR calibration to measure the constituents of milk product was reported by Goulden (1957), the extensive research on the analysis of cheese macrocomponents by NIR spectrophotometry only commenced in the late 70s (Aboshamaa et al., 1977; Birth and Washam, 1978; Washam et al., 1978). Since then, the research has focused on the development of NIR calibrations for predicting nutritional composition of cheese and monitoring the cheese process to optimise cheese quality in the production system.

1) Chemical composition

There are high correlations (R>0.96) between NIR predicted and actually measured content of protein, fat and moisture in cheese (table 1). Wehling and Pierce (1989) reported that fat content, an important quality parameter for hard cheese, can be analysed by NIR, and using multiple wavelengths in the calibration improved the correlation coefficient. However, the inclusion of more than 6 wavelengths did not increase the accuracy of fat prediction. Water content in cheese had a strong influence on the prediction of fat content due to the inclusion of water bands in the fat calibration. Thus freeze drying the samples could improve the prediction (Frank and Birth, 1982 cited by Wehling and Pierce, 1989) and temperature can affect the accuracy of fat prediction for cheese samples by influencing moisture content in the samples. Therefore, the cheese samples need to be equilibrated to a uniform temperature prior to analysis, and the samples used for calibration must be equilibrated to the same temperature as those samples that are to be predicted (Wehling and Pierce, 1989).

Giangiacomo and Nzabonimpa (1994) summarised the sample factors affecting NIR measurement. Physical texture, particle size and its distribution, and bulk density are the important contributors to the variation in fat prediction. However, Baer et al. (1983) suggested that useable predictions of composition of cheese could be obtained even when physical factors such as particle size are not consistent. In contrast to this, Wehling and Pierce (1989) found that the determination of fat content using NIR is more susceptible to sample heterogeneity and packing variability than is the moisture determination, and duplicate readings and samples from each pack are required.

The information on the NIR calibration for protein content in cheese is limited. Rodriguez Otero et al. (1995) scanned 92 cheese samples through a NIR system 6500 with a scanning range from 400-2498 nm and a wavelength increment of 2 nm for the development of calibration, with 25 samples used in validation set. The results showed that protein content in cheese can be predicted as accurately as fat, with a correlation efficient of 0.99. However, the accuracy of protein prediction could be influenced by the variability in the content of non-protein nitrogen in the cheese which is often included in the crude protein measured by Kjeldahl method, and has different NIR spectra from that of true protein. Rodriguez Otero et al. (1995) concluded that NIR is an adequate technique for analysis of cheese without any prior sample treatment, and the method requires that a group of cheeses of similar characteristics, with a range of variation in chemical composition be used for calibration.

2) Cheese processing

During cheese manufacturing, the coagulation of milk is initiated by the addition of proteolytic enzymes. The enzymatic hydrolysis of k-casein de-stabilises the colloidal system, and aggregates the protein micelles into clusters. The clusters grow in size and form a matrix that eventually transforms the milk into a gel. Automation of this cheese making step requires a technique to predict an optimal cut time associated with both yield and quality of cheese (Hicks and Payne, 1994; Saputra et al., 1994). After extensive studying, it has been confirmed that by using fibre optics, the NIR instrument can be interfaced directly to the process stream to provide real-time measurement of coagulum strength and prediction of cutting time, and has advantages of easy installation, less sanitation problems and reliability over the mechanical equipment (Hicks and Payne, 1994). Saputra (1992) reported that wavelengths of 820, 940, 1250 and 1650 could be used to predict the point at which the curd should be cut, and the emitter wavelengths at 820 and 940 nm appeared to be more affected by initial floc formation than wavelengths at 1250 and 1650 nm. Hicks and Payne (1994) also developed a mathematical algorithm, which utilises the sigmoidal inflection kinetic model and the constant time period, to estimate the cutting point of coagulating milk.

Saputra et al. (1994) confirmed that NIR can be used to monitor the rate of hydrolysis of milk and to predict the content of non protein nitrogen produced during hydrolysis over the wavelength of 820-1650 nm, with a correlation coefficient of 0.94. However, NIR diffuse reflectance is sensitive to the milk pH, temperature, enzyme type and concentration, and the concentration of protein, fat and calcium. While protein, fat and calcium content are relatively constant in milk being manufactured into cheese, the diffuse reflectance monitors the state of the coagulating milk (Hicks and Payne, 1994).

As found for the prediction of milk composition, there are overlaps for absorption bands of fat and water. To resolve this, the second derivative should be used and the third derivative avoided due to the increase in spectra noise. This transformation inverts absorbance maxima to minima that are surrounded by positive side-lobes, and reduces the bandwidth, which allows the resolution of overlapping bands (Hall and de Thomas, 1994; Rodriguez Otero et al., 1995).

Other dairy products quality and processing

The potential of using NIR to predict chemical composition of whey and the changes in chemical composition during processing was assessed by Baer (1983) and Pouliot et al. (1997). These researchers showed that NIR can be used to predict the chemical composition of dried whey. The samples used for NIR calibration should be similar in composition to the test samples and represent a limited range of constituent concentrations, indicating that individual calibrations are necessary for each type of dried whey. The calibrations developed using the partial least square technique for monitoring the chemical composition of a whey protein concentrate during manufacturing and the degree of hydrolysis of whey protein during trypsin hydrolysis were related to a variety of products and processing conditions.

While most research focused on the monitoring of quality changes during processing using NIR, some work has also been carried out to identify the temperatures imposed on dairy food during processing. Downey et al. (1989, 1992) reported that NIR can be used as a rapid method to identify the high-, medium- and low-heat dried skim milk, based on the application of discriminant analysis to the factorial coordinates obtained following principal component analysis of NIR spectra. However, the conclusion from these studies was also based on limited number of samples for calibration (34) and validation (32).

GOAT MILK

Protein, fat, and lactose contents have been measured in a goat milk recording scheme in UK using mid infrared spectrometers with fixed wavelengths. Diaz-Carrillo et al. (1992) have calibrated a NIR system to measure concentration of the main milk components and found that these calibrations are sufficient for data required by the recording schemes. In 1995, Diaz-Carrillo (1995) further identified the main NIR absorption peaks from goats milk. The results showed that peaks near 1500 nm and surrounding 1936 nm are due to OH binding from water. A peak located at 1212 nm may be characteristic of protein. The zone located between 1722 and 1764 nm is the characteristic of fat, and the region around 2112 nm may be due to OH groups from lactose. Since the efficiency of milk-to-cheese transformation depends on the total amount of casein, as well as on the relative proportions of the different types of caseins, it is desirable to quantify not only protein, fat and lactose, but also total casein, and alphas-, beta- and kappa-caseins. Diaz Carrillo et al. (1993) used 2000 milk samples from 3 Spanish breeds of goats (Malaguena, Murciano-Granadina, Payoya) to develop NIR calibrations for total protein, total casein, casein fractions (alphas-, beta- and kappa-caseins), fat and lactose. Low standard error and high correlation coefficient were obtained for calibrations and validations, indicating that NIR spectroscopy is a suitable tool to analyse a large number of samples for the dairy goat recording schemes.

BEEF

Meat quality for human consumption is determined by both nutritional quality and sensory characteristics. On-line monitoring of these quality parameters is essential for the quality control program. However, the traditional methods are slow and expensive, and a rapid, non-destructive method needs to be developed.

There is limited information on the potential of using NIR for colour monitoring of meat, presumably because the current method is sufficient and/or the difficulty of developing NIR calibration for colour monitoring. It has been reported that NIR can be used for identifying the grain seeds by colour (van Deynze and Paul, 1994; Ronalds and Blakeney, 1995), but the accuracy is often affected by seed size and the seed position during scanning (Wang et al., 1997). Given that the colour of meat is determined by myoglobin (Clark et al., unpublished data), there maybe potential to develop calibration for the prediction of myoglobin and indirectly to classify the colour of meat.

While NIR application on meat quality measurement was focused on quantitative estimation of the major nutritional components (e.g. protein, fat and water), Hildrum et al. (1994) attempted to develop NIR calibrations to predict sensory characteristics of beef, and found that hardness and tenderness can be predicted using NIR with correlation coefficients in the range of 0.80-0.90. Including samples from all carcases, cows and young bulls, in the model resulted in better predictions for both frozen and thawed samples, but the best prediction was obtained from separate calibrations of samples from the bulls. This suggests that the number of samples should be enough to cover the possible ranges of variation in composition and properties of beef. However, juiceness of beef was not predicted very well with a correlation coefficient of -0.07 to -0.19. Given the limited sample numbers used, more work needs to be done to verify

Table 2. Correlation coefficients, standard error of calibration (SEC) and standard error of performance (SEP) for prediction of meat quality using near infrared (NIR) spectrophotometry

Meat	Source	Parameter	Correlation coefficient**	SEP**	SEC**
Emulsified beef	Kruggel et al. (1981)*	Protein	0.80		
Emulsified beef/pork	Lanza (1983)*	Protein	0.885		
		Moisture	0.99		
Fresh beef	Kim and Yoo (1995)	Moisture	0.984 (75)	0.809 (30)	
		Protein	0.930 (75)	0.743 (30)	
Raw beef	Hong and Yasumato (1996)	Heme iron	0.966 (30)		
		Non-heme iron	0.923 (30)		
Pork	Czarnik-Matusewicz and Korniewicz (1995)	Iodine value in pig back fat	0.942 (165)	1.3 (55)	1.5 (165)
Pork	Lanza (1983)*	Protein	0.89		
Pig carcass	Nuttall et al. (1997)	Crude fat	0.99 (79)		
Ground freeze dried Wet sample		Crude fat	0.98 (58)		
Dwarf chicken carcases	Renden et al. (1986)	Fat	0.92 (49)		
		Moisture	0.94 (49)		
Meat chicken carcases	Valdes and Summers (1986)	Fat	0.95 (45)	2.30-2.32 (54)	2.48-2.51 (45)
		Protein	0.99 (45)	1.03 (54)	0.94 (45)
Meat chicken breast muscle	Valdes and Summers (1986)	Fat	0.88 (30)	3.26 (27)	3.54 (30)
		Protein	0.92 (30)	2.04 (27)	2.67 (30)

* Cited by Kim and Yoo (1995).

** Numbers in bracket are the number of samples used for calibration or validation.

the potential of NIR spectroscopy in the assessment of sensory properties of meat.

The potential of using NIR to predict chemical composition of meat was studied by a number of researchers (Kim and Yoo, 1995; Hong and Yasumoto, 1996; Freudenreich, 1992; table 2). The correlation coefficients of the calibration for protein ranged from 0.80 to 0.89 for emulsified beef (Kruggel et al., 1981; Lanza, 1983 cited by Kim and Yoo, 1995). Kim and Yoo (1995) also demonstrated that NIR can be used as a rapid and non-destructive method for the measurement of protein and moisture content of fresh beef. The multiple correlation coefficients from 4 wavelengths were 0.98 for moisture and 0.93 for protein, with a standard error of prediction (SEP) being 0.81 and 0.74, respectively. Hong and Yasumoto's research also showed that NIR has the potential for estimating heme and nonheme iron in raw meat and allows an *in vitro* estimation of bioavailability of iron in muscle meats. The multiple regression equations (MREs) established for the calibration set between the chemical analysis reference data and the second derivative data of the NIR spectra gave the multiple correlation coefficients of 0.97 and 0.92 for haem and nonhaem iron contents, respectively. The best MREs were obtained with the NIR data recorded at wavelengths where NH groups in protein molecules and C-C and CH in the porphyrin ring of haem give absorption. The correlation coefficients between the data calculated from these MREs and the reference data for the prediction set were 0.99 and 0.91 for haem and nonhaem iron contents, respectively (Hong and Yasumoto, 1996).

Intramuscular fat content (IMF) is a major quality parameter for meat. Eichinger and Beck (1991) used 40 eye-muscle meat samples from beef carcasses with IMF values of 1-11% and 39 samples with unknown IMF content to calibrate and validate the measurement of intramuscular fat (IMF) using NIR. The outcomes showed that the NIR measurements of IMF were identical to those obtained by chemical extraction, and NIR measurements of freshly cut meat samples provided accurate estimation of marbling.

Determination of the previous heat treatment of meat products will give information about whether the heat treatment has been sufficient to destroy pathogenic bacteria, viruses and enzymes. The preliminary study by Isaksson et al. (1989) suggested that NIR may have the potential to determine the temperature used for minced meat treatment. However, the changes in the spectra upon heat treatment are related to protein denaturation and to the state and binding of water in the samples. Thus freeze drying the samples would reduce the prediction errors due to the less complex system without water and the increase in the protein concentration.

An accurate and precise estimate of the concentration of a given component in ground beef is dependent on sample preparation, subsampling and sample analysis. The particle size after grinding, homogeneity of the sample and representative subsamples are the key factors associated with the accuracy of laboratory analysis. However, the accuracy of using NIR to predict fat and moisture content of beef was not affected by sample preparation (emulsification, grinding), the number of subsamples and number of scan locations (Windham, 1995).

PORK

Studies on NIR application in the quality control of pork are very few. In the quality control program, the measurement of iodine value, representing the degree of unsaturation of fats, is one of the routine tests. Holman and Edmondson (1956 cited by Czarnik-Matusewicz and Korniewicz, 1995) suggested that the NIR spectra of fatty acids and esters contains bands at 1180, 2143 and 2190 nm which may be attributed to *cis* unsaturation. Based on this, Czarnik-Matusewicz and Korniewicz (1995) used 165 back fat samples with known iodine values to measure the NIR reflectance spectra over the range of 1100-2500 nm. The results from this study showed that iodine value of pig back fat can be accurately and rapidly determined by NIR with a multiple correlation coefficient of 0.94 (table 2).

It has been reported that crude fat of pig carcass can be predicted in ground freeze-dried samples, with a correlation coefficient of 0.98 (Nuttall et al., 1997). Given the attributes of the fat are responsible for the taste and quality of ham, the analysis of fatty acids in pork or ham using GC become more important in the classification of pig carcases. However, like the other wet chemistry methods, the analyses of fatty acids are expensive and time consuming. Based on the preliminary results of using NIR to estimate palmitic, stearic, oleic and linoleic acid content, de Pedro et al. (1995) suggested that NIR can be useful to classify pig carcases with an acceptable accuracy, using fatty acid content as discriminant variables.

EGG AND CHICKEN MEAT

NIR calibrations for estimating chemical composition of whole eggs have not been well established. Wehling et al. (1988) attempted to develop calibrations for predicting moisture, protein and fat in spray dried whole eggs, and found that moisture can be predicted with an SEP of 0.15% using a calibration based on 3 wavelengths, but protein and fat estimations by NIR were susceptible to variability in particle size of samples. For instance, calibrations with 3 wavelengths measured protein and fat in samples of uniform particle size with a SEP of 0.20 and 0.28%, respectively, but for samples with a variable particle size, the additional wavelengths were required for an accurate estimation (Wehling et al., 1988).

The NIR technique has potential in two areas in chicken meat industry, including poultry carcases inspection and quality monitoring. Research by Park and Chen (1996) showed that textural feature analysis of multispectral images containing visible near-infrared (NIR) wavelengths based on co-occurrence matrices was feasible for discriminating between abnormal and normal poultry carcasses at a wavelength of 542 nm. The classifier developed using statistical regression models had an accuracy of 94.4% for the separation of normal carcasses. While the classification was perfect for separating the normal carcasses from the septicaemia and cadaver carcasses, the accuracy for separating condemned carcasses between septicaemic and cadaver was only 96% and 82.7%, respectively.

Renden et al. (1986) reported that fat and moisture content of ground Dwarf chicken carcase samples can be estimated using NIR with a correlation coefficient over 0.9 between predicted and actually analysed fat and moisture content (table 2), even though the calibrations were based on a small number of samples (49). The calibration equations, however, are dependent upon sample compositions, wavelengths and instrument type. Both temperature and particle size of the sample can influence the accuracy of the calibrations.

The potential of NIR method for predicting fat and protein content in chicken carcases and breast muscles of meat breeders has been also assessed by Valdes and Summers (1986). The crude protein content was predicted using wavelengths over 1759-2190 nm with a correlation coefficient of 0.98 for broiler and 0.92 for laying hen carcase samples. However, the prediction of crude protein in laying hen carcass samples showed a higher standard error of the estimate in comparison with the broiler carcass samples due to the difference between laying hens and broilers in body composition, even though the accuracy of the calibration for fat was not affected by variation in carcase composition.

The prediction of fat and protein content in breast muscle samples was not as accurate as in carcass samples due to the variability in the density of the breast muscle samples caused by packing the samples to an open cup sample holder for obtaining the NIR spectra. This suggests that a closed sample holder might improve the accuracy of prediction (Valdes and Summers, 1986).

FISH

Studies conducted at SARDI Aquaculture Research

Centre and the Pig and Poultry Production Institute indicate a great potential of using NIR to predict protein content in ground abdominal tissue and digestive glands in rock lobster (r^2; 0.80; 0.98, unpublished data). Researchers in other laboratories have also successfully predicted the chemical composition of either ground or whole fish fillets using NIR. Isaksson et al. (1995) used NIR diffuse spectroscopy to estimate fat, moisture and protein contents in whole and ground farmed Atlantic salmon fillets. The samples used in the study had a large variation in fat (9.1-20.5%), moisture (59.9-70.9%) and protein (18.6-20.9%) content. The prediction errors for fat, moisture and protein, expressed as root mean square error, were 6.6, 2.0, 2.0 g/kg for ground and 10.8, 8.5 and 3.7 g/kg for non-destructed whole salmon fillets. The accurate regression models were established using wavelength of 760-1100 nm instead of 1100-2500 nm or 760-2500 nm. Downey (1996) also developed NIR calibrations using the same range of wavelength (700-1100 nm) for analysing oil and moisture content in salmon flesh. The calibrations developed on the dorsal and ventral surfaces of each fish side gave a reliable prediction with a SEP of 2.0-2.4% for oil and 1.45-1.90% for moisture. Wold reported that the multiple correlation coefficient for prediction of fat content of the whole salmon fillets non-destructively using NIR spectra ranged from 0.87 (Wold and Isaksson, 1997) to 0.97 (Wold et al., 1996). The regression models using 6-9 wavelengths in the range of 850-1045 nm gave a more accurate prediction than using 100 wavelengths (Wold and Isaksson, 1997).

CONCLUSION

Near infrared spectroscopy is a rapid, versatile and accurate analytical technique for industrial applications. The calibrations for analysing chemical composition of milk and monitoring the process of cheese production has been developed. New Zealand has accepted NIR analysis as an official method for the analysis of moisture, fat and protein in powdered dairy products, including whole milk, skim milk, casein and whey protein. However, the acceptance in Australia and other countries by industry is very slow even though it has already been proven that NIR analysis of finished products in the factory allows efficient process control.

While some research has shown the potential of NIR for meat quality monitoring, there are no robust calibrations developed for commercial use. Most calibrations are based on limited number of samples and focus on the chemical composition (e.g. protein, fat), but very few studies have considered the sensory characteristics of meat. The sophisticated instrument computer software system for NIR can perform multiple analyses and offer a great opportunity for the development of calibrations to estimate chemical and physical characteristics of meat simultaneously.

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