MULTIELEMENT CONTENT OF RAW AND COOKED BEEF AS DETERMINED BY NEUTRON ACTIVATION ANALYSIS

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SUMMARY

Neutron activation converts a stable isotope into a radioactive nuclide which emits gamma and x-radiation with characteristic energies and half lives. Neutron activation analysis as used to determine twelve elements in beef fat and muscle showed good agreement on muscle content of aluminium, bromine, chlorine, calcium, iodine, sodium, titanium and vanadium with those in the literature. Elemental content ot subcutaneous fat was reduced by roasting while most muscle elemental content increased under these conditions. Chlorine in the raw, subcutaneous fat was highly correlated ($P < 0.01$) with the Armour tenderometer. Thus, determination of chlorine by a portable non-selective electrode in a beef cooler is suggested as a rapid method to predict beef tenderness.

INTRODUCTION

Neutron Activation Analysis (NAA) is a technique in which a stable isotope, when immersed in a flux of neutrons, undergoes a nuclear transformation producing a radioactive nuclide which emits gamma and x-radiation with characteristic energies and half lives Lyon (1964). Activation analysis was defined by Kamen (1951) as a nuclear reaction analogous to a chemical reaction. Furr et al. (1975) reported that animal tissues (liver, kidney muscle and spleen of guinea pigs) were analyzed for 39 elements using NAA. Of the 39 elements they reported, twelve: aluminium (al), bromine (br), calcium (ca), chloride (cl), copper (cu), iodine (I), potassium (k), magnesium (mg), sodium (na), tin (sn), titanium (ti) and vanadium (v) are the subject of this paper.

OBJECTIVES

The objectives were: 1. To determine the usefulness of NAA as a method for determination of elemental content of beef muscle and fat. 2. To determine the elemental loss/gain encountered in cooking- 3. To relate elemental content of beef to its' tenderness.

MATERIALS AND METHODS

Twenty-eight USDA choice carcasses were divided into four groups based on Armour Tenderometer readings, Hansen (1 9 72) as follows : 5.0-6.2 Kg ; 6.3-7.1 Kg; 7.2-8.1 Kg; and 8.2-10.0 Kg. A wholesale rib removed from each carcass was divided into three sections: 6-7-8 ribs for cooking, 9-10-11 ribs for proximate analysis, and 12th rib to obtain the raw cores (1.27 cm dia) for tenderness as described by Bratzler and Smith (1963) and Kramer et al. (1951). The remainder of the 12th rib was used raw for NAA analysis. The 6-7-8 ribs were roasted to an internal temperature of 76°C. The cooked *longissimus* muscle over the eighth rib was sliced 3.81 cm thick and cores 1.27 cm in diameter were removed for machine tenderness values. The remainder was used for NAA analysis. A drip sample was obtained from the roasting pan on removal from the oven. A cooked fat sample was excised from the roast over the eighth fib. The samples were activated as specified by Furr (1971). Standards for al, br, ca, cl, cu, i, k, mg, na, s, sn, ti, and v were run as a reference. A lithium- germanium detector was used to read the gamma-ray emissions. The data were fed to a magnetic tape recorder which read into an IBM 360 computer. The data were analyzed by a computer program designed to print out the element concentration in ppm as described by Roscoe and Furr (1976).

RESULTS AND DISCUSSION

Elemental concentrations in muscle from guinea pigs, Furr et al. (1975); and bovine, Westing (1978) are compared to values obtained in this study, Table 1, Generally, there is good agreement on the muscle content of al, br, cl, ca, i, na, ti and vanadium. The levels of k, mg, and sn were all higher for bovine muscle in this study than those reported by Westing (1978) or those in the guinea pig, Furr et al. (1975). However, the effect of varied elemental levels in the rations of animals was not a part of this study whereas those previously mentioned were designed to study this effect. Roscoe and Furr (1976)

Table 1. Comparisons of element concentration of moisture-free muscle from guinea pigs and bovine.

Element	Guinea Pigs		Bovine			
	Furr, et al. 1975		Westing, 1978		Kelly & Williford 1988	
	ppm	± S.E.	ppm	± S.E.	ppm	± S.E..
Aluminum++	19.6	1.1	8.67	.96	13.4	1.18
Bromine	6.0	2.1	2.47	.19	5.6	0.73
Chlorine	---	---	1103.0	52.78	1239.17	73.68
Calcium	287.0	58.0	99.35	10.29	310.00	28.99
Copper	---	---	45.07	1.89	63.55	0.40
Iodine	---	---	0.14	.09	0.42	0.18
Potassium	10250.0	763.0	1172.7	464.9	15267.62	628.95
Magnesium	832.0	33.0	622.6	24.1	1580.41	85.02
Sodium	1334.0	174.0	1219.0	51.2	1329.69	65.55
Sulfur	12520.0	939.0	---	---	17292.97	1784.73
Tin	<0.5	---	.357	.18	14.48	1.84
Titanium	8.8	1.7	1.86	.37	8.93	1.17
Vandadium	0.05	---	0.12	.0031	.041	0.007

++ Reported as Al + Si in Furr et al 1975.

Table 2. Gains and losses of elements in fat and muscle during cooking

Element	Fat		Muscle	
	% loss	% gain	% loss	% gain
Aluminum	14.5			18.5
Bromine	28.5			43.8
Chlorine	13.1			21.7
Calcium	19.5			1.3
Copper		5.9		61.2
Iodine	50.0		---	---
Potassium		108.4	8.3	
Magnesium		39.1		1.4
Sodium	10.5			9.3
Sulfur	24.6			45.0
Tin	19.7			6.7
Tinanium	22.1			10.8
Vanadium	33.3			41.7

published results obtained by the Neutron Activation laboratory at Virginia and compared them to National Bureau of Standards certified values for bovine liver (NBS-SRM 1577) as reported by Becker (1976). Three bovine liver samples were analyzed from heifers and steers by Westing (1978) who reported that levels of br and mg were within the ranges of those certified. These values have not been established for beef muscle.

Table 2 shows the gains and losses of elements in beef fat and muscle as a result of roasting. Generally, the elements in fat were reduced by roasting. These losses ranged from 10.5% of the na to 50 percent for the i. Only cu, k, and mg increased in fat as a result of roasting. Concentration in the fat when roasted is partially explained by the drip loss.

The back fat liquifies during roasting and bastes the lean portion of the roast where some of the cl ions may be bound. The increase in cl concentration in the cooked lean demonstrates this possibility. In muscle, the pattern observed with fat was reversed. With the exception of k, which was reduced by 8. 3 percent on roasting and i having no change, all of the elements increased as a result of cooking. Percent increases in cu, s, and br were 61. 2, 45.0, 43.8, respectively. Copper is the only element studied which has a recommended dietary allowance by the National Academy of Science (1980). Although pronounced CU deficiencies in the free-living population of the U.S. are very rare, dietary surveys have shown that average intakes far below the recommendation are quite common (Mertz 1981). Since this work reports an increase in the cu content as a result of roasting, bovine muscle may well be recommended as a source of dietary copper. Vanadium content of bovine muscle was also increased in this study by 41.7 percent. Mertz (1981) states "that ranges for the 'new' trace elements, va, ni, si and ar are unknown."

Table 3. Correlations between element content of beef tissues and tenderness.

Element and sample	Armour Tenderometer	Warner-Bratzler	Allo Kramer
Aluminum			
Raw fat	---	---	-.349
Cooked fat	+	---	+
Raw Lean	0.448*	0.252	-.200
Cooked lean	0.387**	---	+
Drip	0.512	+	0.234
Chlorine			
Raw fat	-.612**	-.234	---
Cooked fat	-.452*	---	---
Raw Lean	-.281*	+	---
Cooked lean	-.463*	-.273	-.257
Drip	-.392	+	+
Calcium			
Raw fat	---	---	-.212
Cooked fat	-.310	---	---
Raw Lean	-.230	---	-.210
Cooked lean	---	-.218	-.213
Drip	-0.622**	+	+
Sodium			
Raw fat	-.580**	-.216	---
Cooked fat	-.455**	---	+
Raw Lean	---	---	-.214
Cooked lean	-.442*	-.205	-.276
Drip	-.357	---	---

* = P<.05 ** = P<.01

The correlations of elemental concentration to tenderness of beef as determined by the Armour tenderometer, Hansen (1972) ; the shear device as reported by Bratzler and Smith (1963); and the shear press of Kramer et al. (1951) are presented in Table 3. Chlorine in the raw samples taken from the subcutaneous fat over the longissimus muscle was highly correlated ($P < 0.01$) with the Armour tenderometer measurements. This negative correlation ($r = -.612$) indicates that as the tenderometer readings decrease i.e., the meat becomes more tender, the concentration of total cl in the raw fat increases. The correlations between cl in other tissues i.e., cooked fat, raw lean, cooked lean and the drip are all significant ($P < 0.05$) but not of the magnitude of the raw fat vs. the tenderometer. The highly significant ($P < 0.01$) correlations (data not shown) between concentration of cl in the raw fat and lean, $r = 0.69$, and the cooked fat and lean, $r = 0.67$ show that the content of this element in the fat is highly related to muscle level. This high relationship between cl concentration of the fat and tenderometer value suggests the possibility of taking a back fat sample from the carcass and, based on its cl content, predicting tenderness, or the cl concentration of the fat could be determined rapidly in the cooler by a portable ion-selective electrode. The correlations between the cl concentration and tenderness as measured by the Warner-Bratzler and the Allo-Kramer were not significant. This may be due to using the Armour tenderometer values for the selection of carcasses in this study. As with cl, the tenderometer was found to be significantly correlated with the na content of both raw ($r = -.580$) and cooked ($r = -.455$) fat. The implications concerning nas' decrease in cooked fat and increase in cooked lean are similar to those discussed for cl. Both elements were found in fat and lean but approximately 30 percent more na was lost in the drip (9.99 ppm) than chlorine (7.56 ppm). The strong affinity of the two elements for each other is indicated by the high correlation ($r = 0.97$) between chlorine and sodium in the raw fat. The effect of salt concentration on muscle tenderness has been widely studied and researchers agree that increased salt concentrations in meat increases tenderness, (Deatherage 1963; Wierbicki et al. 1957). A positive correlation ($P < 0.05$) was found between the tenderometer measurements and the al content of raw and cooked lean, $r = 0.45$ and 0.39, respectively. The ca content of the drip was highly negatively correlated ($P < 0.01$) with the tenderometer. None of the other elements determined were highly correlated to tenderness in this study.

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HEAT-INDUCED GELATION OF ACTOMYOSIN BY PRESSURE TREATMENT

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When myosin, which plays an important role in binding capacity and water holding capacity of meat products, is given pressure treatment, gel is formed at low salt concentration around 0.2 M, where myosin usually does not form gel. Myosin exists in meat in the form of actomyosin at the time it is used for processing. Therefore, the effect of pressure treatment on heat-induced gelation of actomyosin was investigated in this study.

Actomyosin was prepared from porcine longissimus muscle by using the method of Szent-Györgye. The prepared samples were adjusted the required pH value (5.0-9.0), the protein concentration (20 mg/g or 30 mg/g) and the salt concentration (KCl; 0.05-1.0 M). The samples were then filled up into plastic containers and pressured up to 150 MPa for 10 min at 0°C. After pressure treatment, the samples in containers; along with non-pressure treated control samples, were heated at 70°C for 30 min, then the gel strength and the work done value were measured. The gel network of actomyosin was observed by scanning electron microscope.

Pressure treatment of actomyosin samples was most effective at pH 6.0, where actomyosin formed gel with fairly high water holding capacity at low salt concentration. The effect of pressure treatment was most remarkable when the pressure employed was raised to 100 MPa in low salt concentration of 0.25 M KCl, and to 150 MPa in high salt concentration of 0.7 M KCl. Such effect continued for at least 15 days. In conclusion, the heat gelling ability of actomyosin was clearly improved by pressure treatment.