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Strontium Isotope Analysis of British Beef Origin: PROJECT II- Improvement of the British Beef Isotope Landscape Map (Isoscape) for Scotland and Northern Ireland

FOR:

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INVESTORS IN PEOPLE

ISO 9001 SYSTEM CERTIFICATION SGS UKAS MANAGEMENT SYSTEMS 005

Job and Sample Information:	
Internal Job No(s):	*2014-20449, 2014-20772, 2015-20873, 2015-21284, 2015-21315, 2015-21384, 2015-21572, 2015-21627 and 2015-21673*
Project Title:	BRITISH BEEF ORIGIN PROJECT II- Improvement of the British Beef Isotope Landscape Map (Isoscape) for Scotland and Northern Ireland
Project Reference:	FS515009
Date Sample(s) Received:	27-10-14, 9-12-14, 5-1-15, 12-3-15, 18-3-15, 2-4-15, 7-5-15, 18-5-15, 27-5-15,
Lab Code	**Client Code**
1190204-1190243, 1196006-1196016, 1196965-1196999, 1201753-1201810, 1202183-1202214, 1203079-1203124, 1206820-1206846, 1207459-1207473, 1208138-1208188	See results tables.

Methods

Methods
Strontium Isotope ratio by Thermal Ionisation Mass Spectrometry – not accredited (based on method AM005)

METHOD DEVELOPMENT:

JHI is UKAS accredited for the measurement of Sr isotope ratios from geochemical samples and has many years' experience in preparing such samples. Initial method development was required to transfer these methodologies from geochemical samples to beef.

Beef has been previously reported to contain high Rubidium (Rb) concentrations (1.65-72 parts per million (mg kg^{-1}, ppm) and low Sr concentrations (0.03-0.55 ppm) (Rummel *et al.* 2012). This is a significant concern as Rb is an interference of Sr isotope ratio determination; therefore it is necessary to efficiently remove Rb from any samples prior to analysis.

A range of reagents and digest protocols were tested to determine which best removed the organic (non-metal) material and produced a total digest of the entire material most efficiently. Removal of organic material was required as it damages the ion exchange columns which are used to isolate Sr from other interfering elements. After optimising the removal of organic material, the elution protocol of the cation exchange columns was optimised. Various muffle temperatures (450°C, 500°C, 550°C, 600°C and 650°C) for efficient beef decomposition, prior to Sr isotope ratio analysis, were also tested. There was evidence of fractionation of $^{87}Sr/^{86}Sr$ when samples were muffled above 500°C. Doubling the initial sample size, applying additional amounts of oxidising agents - hydrogen peroxide (H_2O_2) and nitric acid (HNO_3) and use of different digest vessels/crucibles were trialed to determine the best protocol with minimal blanks.

FINAL METHOD:

Reagents and Instrumentation:

Trace Grade Hydrochloric acid
Trace grade Nitric Acid
Tantalum Activator loading solution
Bio Rad Analytical Grade AG 50W X 8 200-400 mesh hydrogen form
Millipore 18.2Ω water

Smooth walled aluminium dishes
Muffle oven
Drying lamps
3*100mm Glass ion exchange columns
Peristaltic pump
Acid washed PMP (polymethyl-pentene) beakers
Rhenium filament beads
VG Sector 54 Thermal Ionisation Mass Spectrometer

Sample Preparation:

Typically between 1.5 g and 2.7 g of freeze dried and milled beef samples were weighed into smooth walled, aluminium dishes and muffled for eight hours at 500°C to remove the organic matter. Once cooled, 1ml of 2M HNO3, in two additions was added to transfer the sample to an acid washed, single use PMP beaker. The sample was dried under hot lamps, resuspended in 2M HCl and dried again.

The Sr was purified from the digested sample by passing them through calibrated, ion exchange columns (Bio Rad Analytical Grade AG 50W X 8 cation resin in 200-400 mesh hydrogen form) whose flow rate was controlled by a peristaltic pump and only collecting the Sr fraction. The Sr fraction was dried, then loaded onto a rhenium filament with a tantalum activator solution. Full procedure blanks were also carried out by adding a Sr spike to an aluminium dish and following the above procedure.

Instrument Analysis:

During the TIMS procedure the sample filament was preheated and tuned for approximately an hour prior to capturing ratio data. Any ionised Rb not removed by the columns was burnt off during the extended preheat and tuning. The ratios were captured using a three cycle dynamic procedure and the mass fractionation is exponentially corrected for using the naturally invariant $^{86}Sr/^{88}Sr$ ratio of 0.1194. A maximum of 150 ratios were collected.

Quality Control and Reference materials:

The acceptance criteria were applied to each sample, run:

i. a minimum of 50 ratios collected
ii. a Standard error (St Err,%) <0.0060
iii. a 85/86 ratio <0.001
iv. a signal intensity on mass 85 (Rb) <0.00005V.

A NIST certified reference material (CRM), SRM987 – strontium carbonate with a certified value of 0.71034±0.00026 (95% CI) and an in-house assigned value of 0.710250±0.00002 (2SD) n=305, was measured at least twice with each batch of samples. Our mean value for this study was 0.710242±0.000021 (2SD) n=72 (figure 1). There is no general beef tissue CRM available but NRC/CNRC RM8414 (bovine muscle powder) was analysed, producing a ratio of 0.713057±0.000037 (2SE). Several full procedure (muffle to instrument) blanks were carried out throughout the period of analysis.

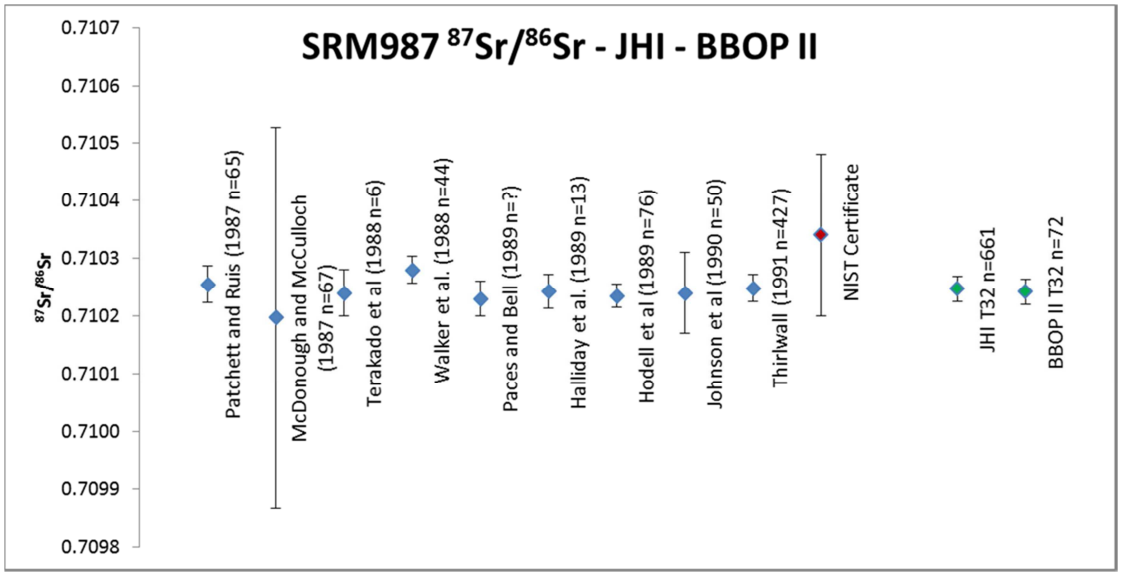

Figure 1. Mean value of SRM987 (±2SD) for this study in comparison to other research groups.

Results

A summary table and the individual Sr ratio results can be found in below.

$^{87}Sr/^{86}Sr$	Scotland	Northern Ireland
Mean	0.708666	0.708122
SD	0.000660	0.000488
Minimum	0.706452	0.706770
Maximum	0.710244	0.708894
Range	0.003792	0.002124
N (number of samples)	250	49

SCOTTISH BEEF

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
				2014-20449				
S14-027973	Plant 1103	UK520764400659	AB42 4NY	1190204	0.709976	0.0037	0.000053	1368
S14-027974	Plant 1103	UK580627201313	AB42 4HA	1190205RR	0.708913	0.0030	0.000043	1388
S14-027975	Plant 1103	UK524375100136	DD10 0TH	1190206	0.708830	0.0025	0.000035	1368
S14-027976	Plant 1103	UK523362401809	IV32 7NN	1190207	0.708815	0.0025	0.000035	1368
S14-027977	Plant 1103	UK508295400025	AB53 8LY	1190208	0.709459	0.0023	0.000033	1368
S14-027978	Plant 1106	UK501952401241	IV12 5SF	1190209RRR	0.709159	0.0037	0.000052	1444
S14-027979	Plant 1106	UK561652201324	EH46 7BB	1190210	0.708491	0.0027	0.000038	1368
S14-027980	Plant 1106	UK523856501412	KW16 3HY	1190211	0.708366	0.0028	0.000040	1368
S14-027981	Plant 1106	UK542961400652	KY16 8QQ	1190212	0.708906	0.0027	0.000038	1368
S14-027982	Plant 1106	UK540304104806	DD9 7PP	1190213	0.708717	0.0024	0.000034	1368
S14-027983	Plant 1106	UK524007300228	AB30 12Q	1190214R	0.708219	0.0019	0.000027	1372
S14-027984	Plant 1541	UK580949402099	KA19 7QT	1190215RRR	0.709913	0.0030	0.000043	1444
S14-027985	Plant 1541	UK542423700636	DG7 3JQ	1190216RR	0.708523	0.0027	0.000038	1456
S14-027986	Plant 1541	UK582089601154	PA11 3RG	1190217R	0.708124	0.0028	0.000040	1444
S14-027987	Plant 1541	UK561568200631	ML12 6HF	1190218	0.709475	0.0021	0.000030	1368
S14-027988	Plant 1101	UK580832101540	KA3 6HT	1190219RR	0.708554	0.0022	0.000031	1456
S14-027989	Plant 1101	UK561060701195	EH49 7PU	1190220	0.708436*	0.0028	0.000040	1464
S14-027990	Plant 1101	UK541663301975	FK14 7NR	1190221	0.709206	0.0022	0.000031	1370
S14-027991	Plant 1101	UK543019402084	G63 0QE	1190222	0.708842	0.0024	0.000034	1370
S14-027992	Plant 1101	UK703368300459	DG1 4LQ	1190223R	0.708674	0.0023	0.000033	1380
S14-027993	Plant 1101	UK542105500369	PH7 3PA	1190224	0.708712	0.0020	0.000028	1370
S14-027994	Plant 1101	UK562282601517	FK1 3AD	1190225R	0.708864	0.0038	0.000054	1380
S14-027995	Plant 1560	UK542696700419	PH4 1QU	1190226R	0.709057	0.0031	0.000044	1380
S14-027996	Plant 1560	UK560575700526	ML12 6JJ	1190227	0.708195	0.0023	0.000033	1370
S14-027997	Plant 1560	UK560553300926	PA7 5NN	1190228R	0.707983	0.0026	0.000037	1380
S14-027998	Plant 1560	UK563705301903	TD8 6LU	1190229RR	0.707934	0.0028	0.000040	1456
S14-027999	Plant 1560	UK542939401028	FK7 8AB	1190230R	0.708197	0.0029	0.000041	1444
S14-028000	Plant 1560	UK584742101065	DG12 5NQ	1190231	0.708745	0.0026	0.000037	1370
S14-028001	Plant 1560	UK561158600907	G66 7NW	1190232R	0.708066	0.0025	0.000035	1380

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S14-030087	Plant 1101	UK560706101370	PA14 6YN	1190233R	0.709628	0.0024	0.000034	1444
S14-030088	Plant 1101	UK504747300005	PH26 3PS	1190234	0.710052	0.0023	0.000033	1372
S14-030089	Plant 1101	UK564325200174	TD9 8QW	1190235RR	0.709781	0.0038	0.000054	1400
S14-030091	Plant 1101	UK581607401798	DG12 5PY	1190236	0.708658	0.0031	0.000044	1372
S14-030092	Plant 1101	UK561252301435	EH49 7PU	1190237	0.709534	0.0035	0.000050	1372
S14-032351	Plant 1756	UK524328400360	ZE2 9RU	1190238	0.707438	0.0022	0.000031	1372
S14-032352	Plant 1756	UK524349600306	ZE1 0US	1190239	0.709293	0.0021	0.000030	1372
S14-032353	Plant 1756	UK526471600028	ZE2 9PP	1190240	0.709352	0.0024	0.000034	1372
S14-032354	Plant 1756	UK524219300365	ZE2 9EL	1190241	0.708881	0.0022	0.000031	1372
S14-032355	Plant 1756	UK524375600057	ZE2 9NL	1190242	0.708889	0.0033	0.000047	1372
S14-043351	Retail Sample	FERA QC	N/A	1190243	0.709344	0.0040	0.000057	1388
				2014-20772				
S14-030065	Plant 1106	UK580803400757	DD9 7XP	1196006	0.708674	0.0028	0.000040	1372
S14-030069	Plant 1106	UK500585201396	IV2 7QT	1196007R	0.708947	0.0022	0.000031	1456
S14-030073	Plant 1560	UK562286501335	FK1 3AT	1196008R	0.710017	0.0024	0.000034	1388
S14-030077	Plant 1541	UK582199503123	DG2 8JE	1196009	0.709302	0.0040	0.000057	1376
S14-030078	Plant 1541	UK560602200911	ML12 6NS	1196010	0.706590	0.0022	0.000031	1376
S14-030080	Plant 1541	UK541323700487	KA16 9BD	1196011	0.707407	0.0021	0.000030	1376
S14-043895	Plant 1560	UK560239703662	TD10 6XS	1196012	0.708686	0.0032	0.000045	1380
S14-043896	Plant 1560	UK585851500487	DD81XN	1196013	0.708349	0.0025	0.000035	1380
S14-043897	Plant 1560	UK540815701746	PA296UT	1196014	0.709719	0.0023	0.000033	1380
S14-043898	Plant 1560	UK581776200580	DG140YG	1196015	0.708887	0.0023	0.000033	1380
S14-053098	Plant 1101	UK 542390 202049	PH8 0HH	1196016RR	0.708634	0.0022	0.000031	1464
				2015-20873				
S14-042543	Plant 1103	UK500705500974	IV63 6TN	1196965	0.710229	0.0021	0.000030	1380
S14-042544	Plant 1103	UK528251500073	AB45 2AN	1196966	0.708062	0.0023	0.000033	1382
S14-042545	Plant 1103	UK104262201276	AB42 0QY	1196967RR	0.709076	0.0044	0.000062	1438
S14-042546	Plant 1106	UK541767602718	KY7 6LJ	1196968	0.708668	0.0033	0.000047	1382
S14-042547	Plant 1106	UK500288401497	KW14 8XH	1196969	0.708942	0.0019	0.000027	1382
S14-042548	Plant 1106	UK543053102891	DD9 7QP	1196970	0.708334	0.0035	0.000050	1382
S14-042549	Plant 1106	UK560474601247	EH39 5LN	1196971	0.707841	0.0020	0.000028	1382

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S14-042550	Plant 1106	UK582195100794	DD9 6TD	1196972	0.708857	0.0019	0.000027	1382
S14-042551	Plant 1101	UK542974505663	G63 9QN	1196973RR	0.707945	0.0024	0.000034	1438
S14-042552	Plant 1101	UK560338300769	G65 9LN	1196974	0.708548	0.0031	0.000044	1388
S14-042553	Plant 1101	UK562455701458	EH48 4LN	1196975R	0.707776	0.0021	0.000030	1400
S14-042554	Plant 1101	UK542717103017	FK15 8PF	1196976R	0.709374	0.0031	0.000044	1546
S14-042555	Plant 1101	UK522774101820	FK16 6EQ	1196977	0.708827	0.0021	0.000030	1388
S14-042556	Plant 1541	UK561956401584	TD5 8AA	1196978RRRR	0.708806	0.0021	0.000030	1464
S14-042557	Plant 1541	UK580440301598	KA5 5HS	1196979	0.708352	0.0033	0.000047	1388
S14-042558	Plant 1541	UK560706301372	PA14 6YN	1196980	0.709380	0.0022	0.000031	1388
S14-042559	Plant 1541	UK582951104406	DG7 1RE	1196981	0.708562	0.0036	0.000051	1400
S14-042560	Plant 1560	UK561405201250	EH27 8DQ	1196982	0.708565	0.0026	0.000037	1388
S14-042561	Plant 1560	UK542297100287	PH13 9JS	1196983	0.708559	0.0042	0.000060	1388
S14-042562	Plant 1560	UK915158207284	KA26 0JQ	1196984RR	0.707841	0.0026	0.000037	1440
S14-042563	Plant 1560	UK541990202166	KY13 0nz	1196985	0.707994	0.0023	0.000033	1400
S14-042564	Plant 1756	UK524314600236	ZE2 9RE	1196986	0.708884	0.0021	0.000030	1400
S14-042565	Plant 1756	UK524397300014	ZE2 9NL	1196987	0.708746	0.0019	0.000027	1400
				2015-21284				
S14-030064	Plant 1106	UK523523300597	KW17 2LS	1201753	0.708874	0.0020	0.000028	1400
S14-030066	Plant 1106	UK500157400080	AB54 7YE	1201754RR	0.708442	0.0024	0.000034	1464
S14-030067	Plant 1106	UK561514203666	EH22 2NL	1201755	0.709218	0.0040	0.000057	1402
S14-030068	Plant 1106	UK542213401354	KY7 6LN	1201756	0.708355	0.0031	0.000044	1402
S14-030070	Plant 1560	UK580358600912	KA18 4NS	1201757	0.708442	0.0019	0.000027	1402
S14-030071	Plant 1560	UK543016305311	G63 0QW	1201758RR	0.710016	0.0025	0.000036	1464
S14-030072	Plant 1560	UK562332400999	EH49 6LW	1201759R	0.708541	0.0021	0.000030	1440
S14-030074	Plant 1560	UK540035201497	DD9 7UG	1201760	0.708720	0.0034	0.000048	1402
S14-030075	Plant 1560	UK540637502648	PA28 6PW	1201761RRR	0.708549	0.0021	0.000030	1444
S14-030076	Plant 1541	UK580117601452	G74 5AL	1201762	0.709021	0.0028	0.000040	1402
S14-030079	Plant 1541	UK562080302706	TD1 2ND	1201763	0.709690	0.0024	0.000034	1402
S14-030081	Plant 1103	UK544583700364	DD10 0TH	1201764	0.709559	0.0028	0.000040	1402
S14-030082	Plant 1103	UK524116500588	AB51 8XT	1201765R	0.709155	0.0039	0.000055	1440
S14-030083	Plant 1103	UK521618600829	IV32 7LN	1201766	0.708393	0.0022	0.000031	1402

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S14-030084	Plant 1103	UK501964502575	IV32 7LN	1201767	0.708439	0.0029	0.000041	1402
S14-030085	Plant 1103	UK500995400573	IV10 8SN	1201768	0.708680	0.0029	0.000041	1402
S14-030086	Plant 1101	UK562369500451	EH49 7PU	1201769	0.708341	0.0023	0.000033	1402
S14-030090	Plant 1101	UK580477101306	KA26 0PD	1201770	0.708356	0.0036	0.000051	1402
S14-043883	Plant 1101	UK561067 301485	ML10 6TY	1201771	0.708577	0.0031	0.000044	1406
S14-043884	Plant 1101	UK560184 100270	PA13 4TE	1201772	0.709718	0.0025	0.000035	1406
S14-043885	Plant 1101	UK560215601205	EH49 7PV	1201773	0.708345	0.0022	0.000031	1406
S14-043886	Plant 1101	UK582604402924	DG2 8JU	1201774	0.709327	0.0026	0.000037	1406
S14-043887	Plant 1101	UK580963305479	KA19 7SQ	1201775	0.708018	0.0031	0.000044	1402
S14-043888	Plant 1103	UK520578 604293	AB43 8SE	1201776RR	0.709484	0.0024	0.000034	1426
S14-043889	Plant 1103	UK501296 400300	IV7 8LY	1201777	0.709783	0.0032	0.000045	1406
S14-043890	Plant 1103	UK523527 300514	AB51 7L J	1201778R	0.707714	0.0031	0.000044	1456
S14-043891	Plant 1106	UK540211101848	DD8 1PW	1201779R	0.707954	0.0022	0.000031	1418
S14-043892	Plant 1106	UK523828700322	KW16 3LT	1201780RR	0.710244	0.0022	0.000031	1426
S14-043893	Plant 1106	UK543108202008	KY12 9TD	1201781R	0.708817	0.0029	0.000041	1418
S14-043894	Plant 1106	UK500605102702	IV7 8LL	1201782	0.709228	0.0058	0.000082	1406
S14-044028	Plant 1541	UK583090600741	DG89DH	1201783	0.708779	0.0041	0.000058	1406
S14-044029	Plant 1541	UK580947101651	KA197PY	1201784	0.708880	0.0032	0.000045	1406
S14-044030	Plant 1541	UK560263702667	TD26SF	1201785R	0.709220	0.0020	0.000028	1444
S14-049697	Plant 1560	UK523857700807	KW17 2JF	1201786	0.708407	0.0025	0.000035	1406
S14-051299	Plant 1101	UK560931 600152	ML12 6QZ	1201787RR	0.708121	0.0023	0.000033	1426
S14-051300	Plant 1101	UK540848 601076	PA28 6RW	1201788R	0.708573	0.0020	0.000028	1418
S14-051301	Plant 1101	UK560616 501768	FK15 9JS	1201789	0.708580	0.0032	0.000045	1410
S14-051302	Plant 1101	UK541663 202030	FK14 7NR	1201790	0.708317	0.0024	0.000034	1410
S14-051303	Plant 1101	UK540642 201857	G62 6HA	1201791	0.709426	0.0021	0.000030	1410
S14-051304	Plant 1103	UK502160 500272	IV15 9TP	1201792	0.709311	0.0023	0.000033	1410
S14-051305	Plant 1103	UK509039 100740	IV2 6DN	1201793R	0.708003	0.0052	0.000074	1418
S14-051306	Plant 1103	UK523585 401317	AB41 8TE	1201794R	0.709266	0.0036	0.000051	1458
S14-051307	Plant 1106	UK541447503449	KY155PN	1201795	0.707878	0.0025	0.000035	1410
S14-051308	Plant 1106	UK560366703986	DD9 7RQ	1201796	0.708776	0.0029	0.000041	1410
S14-051309	Plant 1106	UK561061401824	DD9 7QP	1201797RR	0.708702	0.0026	0.000037	1426

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S14-051310	Plant 1106	UK523874100499	KW172DP	1201798	0.708282	0.0034	0.000048	1412
S14-051311	Plant 1106	UK541446402529	DD10 0HX	1201799R	0.708287	0.0022	0.000031	1418
S14-051312	Plant 1560	UK 582491702470	DG7 2EW	1201800R	0.708794	0.0024	0.000034	1418
S14-051313	Plant 1560	UK540719401278	PA28 6QP	1201801R	0.708705	0.0023	0.000033	1418
S14-051314	Plant 1560	UK561500702733	EH26 0PE	1201802	0.709313	0.0027	0.000038	1416
S14-051315	Plant 1560	UK560114100473	TD106XT	1201803R	0.709218	0.0024	0.000034	1426
S14-051569	Plant 1118	UK507342 600011	HS2 0RS	1201804	0.708902	0.0026	0.000037	1416
S14-051570	Plant 1118	UK508552 500001	HS2 0NW	1201805RR	0.709617	0.0022	0.000031	1436
S14-051571	Plant 1118	UK506292 600004	HS2 0PU	1201806R	0.709385	0.0024	0.000034	1436
S14-051572	Plant 1118	UK502430 100017	HS2 0AZ	1201807R	0.709641	0.0023	0.000033	1458
S14-052425	Plant 1541	UK582662604449	DG7 3EU	1201808	0.709888	0.0022	0.000031	1416
S14-052426	Plant 1541	UK582307205163	DG2 8JE	1201809	0.709612	0.0028	0.000040	1416
S14-052427	Plant 1541	UK542066100973	G745 AL	1201810R	0.709370	0.0030	0.000043	1426
				2015-21315				
S14-049679	Plant 1106	UK 540286601695	DD11 3RT	1202195	0.708298	0.0029	0.000041	1420
S14-049680	Plant 1106	UK 523280401309	IV30 1YE	1202196	0.707557	0.0028	0.000040	1420
S14-049681	Plant 1106	UK 585435600790	DD10 OHX	1202197	0.709083	0.0027	0.000038	1420
S14-049682	Plant 1106	UK 523925402508	KW16 3HU	1202198R	0.709016	0.0021	0.000030	1458
S14-049683	Plant 1106	UK 524051601250	KW172QH	1202199	0.709398	0.0022	0.000031	1420
S14-049684	Plant 1103	UK500951700355	AB54 6BW	1202200	0.708176	0.0021	0.000030	1420
S14-049685	Plant 1103	UK501226600169	AB45 2UL	1202201	0.708703	0.0021	0.000030	1420
S14-049686	Plant 1103	UK500743601317	IV36 2RA	1202202	0.707945	0.0019	0.000027	1420
S14-049687	Plant 1103	UK525368300094	IV30 7PR	1202203	0.709872	0.0021	0.000030	1420
S14-049688	Plant 1101	UK540847 200377	PH2 8PT	1202204	0.708422	0.0035	0.000050	1420
S14-049689	Plant 1101	UK561917 403074	TD12 4NE	1202205R	0.708390	0.0021	0.000030	1428
S14-049690	Plant 1101	UK562260 700186	G65 9LH	1202206R	0.708348	0.0024	0.000034	1428
S14-049691	Plant 1101	UK562455 601471	EH49 7PU	1202207R	0.709061	0.0031	0.000044	1436
S14-049692	Plant 1560	UK 561158300953	G66 7NW	1202208RR	0.708245	0.0017	0.000024	1444
S14-049693	Plant 1560	UK581258300315	FK7 8EX	1202209	0.708252	0.0021	0.000030	1428
S14-049694	Plant 1560	UK540277401430	DD8 5NT	1202210RR	0.708160	0.0024	0.000034	1444
S14-049695	Plant 1560	UK 542311600124	PH10 7JH	1202211	0.708498	0.0040	0.000057	1428

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S14-049696	Plant 1560	UK 560896301031	ML1 5LT	1202212	0.710003	0.0022	0.000031	1428
S14-050060	Plant 1541	UK 580584702422	KA26 9JD	1202213	0.707963	0.0028	0.000040	1428
S14-050061	Plant 1541	UK 523857700807	ML12 6HF	1202214	0.708933	0.0028	0.000040	1428
				2015-21384				
S14-053097	Plant 1101	UK 544971 100504	PH10 7LS	1203079	0.709307	0.0032	0.000045	1428
S14-053099	Plant 1101	UK 580116 500063	KA1 5NN	1203080	0.707011	0.0024	0.000034	1428
S14-053100	Plant 1101	UK 564360 400092	ML1 5PL	1203081	0.709027	0.0034	0.000048	1428
S14-053101	Plant 1101	UK 560529 204272	EH54 9AW	1203082	0.708535	0.0027	0.000038	1428
S14-053102	Plant 1101	UK 580584 102437	KA26 9JD	1203083	0.707945	0.0036	0.000051	1430
S14-053103	Plant 1101	UK 581609 401207	DG1 4RL	1203084RR	0.707987	0.0026	0.000037	1444
S14-054362	Plant 1106	UK561448201084	EH37 5XP	1203085	0.707706	0.0022	0.000031	1430
S14-054363	Plant 1106	UK524036700269	DD9 7ON	1203086	0.708654	0.0023	0.000033	1430
S14-054364	Plant 1106	UK540466602069	DD4 0RF	1203087	0.707771	0.0035	0.000050	1430
S14-054365	Plant 1106	UK541447203831	KY15 5PN	1203088	0.708222	0.0021	0.000030	1430
S14-054367	Plant 1560	UK561932405337	TD8 6LU	1203089	0.708569	0.0021	0.000030	1430
S14-054368	Plant 1560	UK562465201641	EH49 7NE	1203090RR	0.708361	0.0027	0.000038	1444
S14-054369	Plant 1560	UK560664601193	ML11 9XA	1203091	0.708265	0.0024	0.000034	1430
S14-054370	Plant 1560	UK561482703131	TD1 1UH	1203092	0.707641	0.0024	0.000034	1430
S14-054371	Plant 1560	UK523679200719	KW172RY	1203093	0.708429	0.0021	0.000030	1430
S14-054372	Plant 1101	UK 580883 601465	KA1 5LR	1203094	0.708931	0.0023	0.000033	1430
S14-054373	Plant 1101	UK 540848 701091	PA28 6RW	1203095	0.708350	0.0020	0.000028	1430
S14-054374	Plant 1101	UK 582118 600428	DG11 1LW	1203096	0.708861	0.0022	0.000031	1430
S14-054375	Plant 1103	UK522644 300967	AB45 3QD	1203097	0.706979	0.0026	0.000037	1430
S14-054376	Plant 1103	UK521484 601457	AB42 5RW	1203098	0.709258	0.0023	0.000033	1430
S14-054377	Plant 1103	UK521823 702059	AB54 6AX	1203099	0.708846	0.0032	0.000045	1430
S14-054378	Plant 1103	UK500094 100889	IV10 8SN	1203100	0.707873	0.0022	0.000031	1430
S15-023560	Plant 1103	UK502102 503362	IV16 9UU	1203101	0.708012	0.0029	0.000041	1432
S15-023564	Plant 1106	UK523675303932	DD8 2JN	1203102	0.708201	0.0021	0.000030	1432
S15-039012	Plant 1101	UK580560201802	PH7 3RU	1203103	0.708352	0.0022	0.000031	1432
S15-039013	Plant 1101	UK581576100774	DG1 4JS	1203104	0.708255	0.0020	0.000028	1432

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S15-039014	Plant 1101	UK581845100647	DG11 1BW	1203105	0.708797	0.0021	0.000030	1432
S15-039015	Plant 1101	UK580104401039	KA5 5LP	1203106	0.707982	0.0023	0.000033	1432
S15-039016	Plant 1101	UK106530301088	TD15 2QA	1203107	0.708691	0.0021	0.000030	1432
S15-039017	Plant 1101	UK561425401600	EH23 4RZ	1203108R	0.709179	0.0024	0.000034	1436
S15-039018	Plant 1103	UK502764701930	IV19 1LZ	1203109	0.709258	0.0022	0.000031	1432
S15-039019	Plant 1103	UK502039100243	IV1 3UD	1203110	0.709043	0.0025	0.000035	1434
S15-039020	Plant 1103	UK560538401100	AB43 6NU	1203111	0.708956	0.0024	0.000034	1434
S15-039021	Plant 1103	UK521138605658	AB53 5QD	1203112	0.707832	0.0026	0.000037	1434
S15-039022	Plant 1103	UK581854500613	AB53 5YP	1203113	0.709143	0.0022	0.000031	1434
S15-039023	Plant 1560	UK 561484501852	EH38 5YD	1203114R	0.709181	0.0024	0.000034	1438
S15-039024	Plant 1560	UK 540735701075	PA7 5NN	1203115R	0.708521	0.0050	0.000071	1438
S15-039025	Plant 1560	UK560003506149	TD11 3RS	1203116R	0.708875	0.0024	0.000034	1438
S15-039026	Plant 1560	UK583168100969	PA9 1AB	1203117	0.708265	0.0019	0.000027	1434
S15-039027	Plant 1560	UK562469601212	EH52 6NH	1203118	0.708628	0.0023	0.000033	1434
S15-039028	Plant 1106	UK521134103055	DD9 9LA	1203119	0.708660	0.0021	0.000030	1434
S15-039029	Plant 1106	UK523847401785	KW16 3LP	1203120	0.709115	0.0021	0.000030	1434
S15-039030	Plant 1106	UK523593301927	KW17 2JR	1203121R	0.709712	0.0033	0.000047	1458
S15-039031	Plant 1106	UK523007503515	DD10 0SU	1203122	0.708616	0.0033	0.000047	1434
S15-039032	Plant 1106	UK541832300199	KY16 8QQ	1203123	0.708865	0.0022	0.000031	1434
S15-039033	Plant 1106	UK541935500918	KY4 0HX	1203124	0.706687	0.0021	0.000030	1434
				2015-21572				
S14-054366	Plant 1560	UK545233700145	FK9 3LZ	1206820	0.708691	0.0033	0.000047	1434
S15-023552	Plant 1101	UK 562287 201271	FK1 3AH	1206821	0.708392	0.0022	0.000031	1434
S15-023553	Plant 1101	UK 581571 401145	DG1 4JS	1206822	0.708698	0.0023	0.000033	1434
S15-023554	Plant 1101	UK 582103400515	DG11 1AN	1206823	0.707604	0.0025	0.000035	1436
S15-023555	Plant 1101	UK 542087 405085	PH2 7PL	1206824	0.707646	0.0019	0.000027	1436
S15-023556	Plant 1101	UK 581006 700928	G62 6HA	1206825R	0.708224	0.0020	0.000028	1444
S15-023557	Plant 1101	UK 540121 101332	KA26 9JD	1206826	0.707656	0.0027	0.000038	1436
S15-023559	Plant 1103	UK502271 701224	IV18 0LL	1206827R	0.708894	0.0020	0.000028	1444
S15-023561	Plant 1106	UK503646 300064	AB53 8NY	1206828	0.708974	0.0026	0.000037	1436
S15-023563	Plant 1106	UK502084400889	IV20 1RG	1206829	0.708878	0.0021	0.000030	1436

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S15-023567	Plant 1560	UK948420402684	PA6 7EE	1206830	0.708120	0.0020	0.000028	1436
S15-023569	Plant 1560	UK560266302214	TD2 6QR	1206831	0.708540	0.0025	0.000035	1438
S15-023570	Plant 1560	UK543017102224	G63 0QB	1206832R	0.708738	0.0022	0.000031	1446
S15-023571	Plant 1560	UK561975303637	TD5 8QX	1206833	0.708437	0.0029	0.000041	1438
S15-023572	Plant 1560	UK523922500739	KW16 3EX	1206834	0.708449	0.0019	0.000027	1438
				2015-21673				
S14-053104	Plant 1103	UK523459 503915	IV30 8RS	1208138	0.708980	0.0025	0.000035	1442
S14-053105	Plant 1103	UK502123 701292	IV19 1QS	1208139	0.709679	0.0028	0.000040	1442
S14-053106	Plant 1103	UK561591 301308	AB53 6YQ	1208140	0.709036	0.0025	0.000035	1442
S14-053107	Plant 1103	UK502837 700564	AB56 5ES	1208141R	0.709465	0.0022	0.000031	1458
S14-053108	Plant 1106	UK523844401303	AB392TL	1208142R	0.708705	0.0024	0.000034	1458
S14-053109	Plant 1106	UK540466602090	DD4 0RF	1208143	0.708316	0.0024	0.000034	1446
S14-053110	Plant 1106	UK560366304038	DD9 7RQ	1208144R	0.708553	0.0021	0.000030	1458
S14-053111	Plant 1106	UK561497703084	EH23 4SB	1208145RR	0.708670	0.0023	0.000033	1466
S14-053112	Plant 1106	UK541422400514	KY14 6HZ	1208146	0.707935	0.0021	0.000030	1446
S14-053113	Plant 1560	UK542026400280	PH3 1DR	1208147	0.707316	0.0022	0.000031	1446
S14-053114	Plant 1560	UK107594300514	G78 3AJ	1208148	0.706452	0.0021	0.000030	1446
S14-053115	Plant 1560	UK581863701004	DG11 3JL	1208149	0.709037	0.0023	0.000033	1448
S14-053116	Plant 1560	UK 562008504349	TD15 1XG	1208150	0.709566	0.0021	0.000030	1448
S14-053117	Plant 1560	UK523007203470	DD10 0SU	1208151	0.708714	0.0021	0.000030	1448
S14-053823	Plant 1118	UK505313700021	HS2 0QY	1208152	0.709889	0.0022	0.000031	1448
S14-053824	Plant 1118	UK502505600018	HS2 9DY	1208153RR	0.709595	0.0023	0.000033	1466
S14-053825	Plant 1118	UK507342600018	HS5 3UD	1208154	0.709277	0.0022	0.000031	1448
S15-023558	Plant 1103	UK501004 700594	IV2 6DL	1208155R	0.709992	0.0031	0.000044	1458
S15-023562	Plant 1106	UK 540466702105	DD4 0RF	1208156	0.707930	0.0027	0.000038	1448
S15-023565	Plant 1106	UK541465600889	KY15 7HX	1208157	0.708120	0.0021	0.000030	1448
S15-023566	Plant 1106	UK540331502477	DD11 3RT	1208158	0.708213	0.0030	0.000042	1448
S15-023568	Plant 1560	UK582055301559	DG11 2NJ	1208159	0.707226	0.0024	0.000034	1448
S15-040748	Plant 1560	UK540754101177	EH519SN	1208160	0.707708	0.0020	0.000028	1448
S15-040749	Plant 1560	UK540719301256	PA28 6QP	1208161	0.708683	0.0023	0.000033	1448
S15-040750	Plant 1560	UK583496301200	ML20RW	1208162	0.709066	0.0022	0.000031	1448

Name	Plant	External Reference (ear tag number)	Postcode	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
S15-040751	Plant 1560	UK503180700004	EH345DT	1208163	0.708146	0.0023	0.000033	1448
S15-040752	Plant 1560	UK906232804611	KA260JY	1208164	0.708254	0.0023	0.000033	1448
S15-040753	Plant 1101	UK 543978 600126	PH14 9QW	1208165	0.708768	0.0024	0.000034	1448
S15-040754	Plant 1101	UK 560819 101148	ML11 8LP	1208166	0.708415	0.0022	0.000031	1448
S15-040755	Plant 1101	UK 542983 500102	G63 0NQ	1208167R	0.708291	0.0026	0.000037	1458
S15-040756	Plant 1101	UK542699 600879	FK15 9JU	1208168RR	0.708358	0.0031	0.000044	1466
S15-040757	Plant 1103	UK520526 200937	AB43 7AH	1208169	0.708689	0.0019	0.000027	1450
S15-040758	Plant 1103	UK544851 700088	IV4 7HU	1208170	0.708793	0.0029	0.000041	1450
S15-040759	Plant 1106	UK 541063 600330	DD10 0TA	1208171	0.708696	0.0023	0.000033	1450
S15-040760	Plant 1106	UK 561335 701794	DD9 7QP	1208172	0.708479	0.0021	0.000030	1450
S15-040761	Plant 1106	UK 523922 100763	KW16 3EX	1208173R	0.708600	0.0034	0.000048	1460
S15-040762	Plant 1106	UK 542087 604744	KY16 8PW	1208174	0.707698	0.0021	0.000030	1450
S15-040763	Plant 1106	UK 541465 700897	KY15 7HX	1208175	0.708065	0.0025	0.000035	1450

*In-house acceptance iii criteria fail.

NORTHERN IRISH BEEF

Sample Reference No	County	cattle passport	County of last holding	IGFS ID	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
					2015-20873				
9012-06-01	Antrim	UK 9 152372 1006 5	AN	MHANI001	1196988	0.707424	0.0044	0.000062	1388
9012-06-02	Armagh	UK 9 210090 0839 4	AR	MHANI002	1196989	0.708299	0.0041	0.000058	1390
9023-06-01	Down	UK 9 372345 2952 4	DO	MHANI003	1196990RR	0.708518	0.0029	0.000041	1440
9023-06-02	Fermanagh	UK 9 451497 0838 2	FE	MHANI004	1196991	0.707825	0.0030	0.000042	1390
9023-06-03	Londonderry	UK 9 956726 2179 6	LD	MHANI005	1196992	0.707886	0.0023	0.000033	1390
9012-07-01	Tyrone	UK 9 452961 0611 7	TY	MHANI006	1196993	0.708389	0.0033	0.000047	1390
9012-07-02	Antrim	UK 9 060833 3835 6	AN	MHANI007	1196994R	0.706882	0.0027	0.000038	1400
9012-07-03	Armagh	UK 9 180483 1901 7	AR (030)	MHANI008	1196995	0.708629	0.0034	0.000048	1390
9023-07-01	Down	UK 9 372221 1550 3	DO	MHANI009	1196996RRRRRR	0.708768	0.0022	0.000031	1476
9023-07-02	Fermanagh	UK 9 472370 0287 7	FE	MHANI010	1196997RR	0.708335	0.0022	0.000031	1440

Sample Reference No	County	cattle passport	County of last holding	IGFS ID	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
9012-08-01	Londonderry	UK 9 492231 1486 6	LD	MHANI011	1196998RR	0.707969	0.0024	0.000034	1440
9012-08-02	Tyrone	UK 9 520651 0049 1	TY	MHANI012	1196999	0.708763	0.0028	0.000040	1390
					2015-21315				
9023-08-01	Antrim	UK 9 564502 0029 7	AN	MHANI013	1202183RR	0.707395	0.0025	0.000035	1436
9023-08-02	Armagh	UK 9 243757 0508 4	AR	MHANI014	1202184	0.707835	0.0027	0.000038	1418
9012-09-01	Fermanagh	UK 9 472251 2185 1	FE	MHANI016	1202185	0.708528	0.0026	0.000037	1418
9012-09-03	Tyrone	UK 9 451844 1821 7	TY	MHANI018	1202186	0.708291	0.0025	0.000035	1418
9023-09-01	Antrim	UK 9 150580 2867 4	AN	MHANI019	1202187	0.707079	0.0027	0.000038	1418
9023-09-02	Antrim	UK 9 483879 0267 5	AR	MHANI020	1202188	0.708417	0.0029	0.000041	1418
9012-10-01	Down	UK 9 331898 0653 4	DO	MHANI021	1202189R	0.708294	0.0023	0.000033	1428
9012-10-02	Fermanagh	UK 9 450698 0784 7	FE	MHANI022	1202190R	0.707445	0.0024	0.000034	1428
9023-10-01	Londonderry	UK 9 060638 0362 2	LD	MHANI023	1202191	0.708034	0.0022	0.000031	1420
9023-10-02	Tyrone	UK 9 422274 0310 7	TY	MHANI024	1202192R	0.708523	0.0022	0.000031	1428
9012-11-01	Armagh	UK 9 651840 3810 4	AR	MHANI026	1202193RR	0.708894	0.0026	0.000037	1436
9012-11-03	Fermanagh	UK 9 484856 0333 3	FE	MHANI028	1202194	0.708344	0.0020	0.000028	1420
					2015-21572				
9023-08-03	Down	UK 9 331480 0541 5	DO	MHANI015	1206835R	0.707942	0.0023	0.000033	1446
9023-03-01	Antrim	UK 9 103020 0032 3	AN	MHANI049	1206836	0.708006	0.0024	0.000034	1438
9023-10-03	Antrim	UK 9 060562 3283 1	AN	MHANI025	1206837	0.707551	0.0022	0.000031	1440
9012-11-02	Down	UK 9 184910 1679 1	DO	MHANI027	1206838	0.708407	0.0024	0.000034	1440
9012-12-01	Antrim	UK 9 120437 1808 5	AN	MHANI031	1206839R	0.708222	0.0021	0.000030	1446
9012-12-02	Armagh	UK 9 210216 2483 3	AR	MHANI032	1206840	0.708240	0.0022	0.000031	1440
9012-01-01	Tyrone	UK 9 415250 1827 7	TY	MHANI036	1206841R	0.708057	0.0027	0.000038	1446
9012-01-02	Antrim	UK 9 120722 3103 4	AN	MHANI037	1206842	0.707969	0.0021	0.000030	1440
9012-01-03	Armagh	UK 9 211631 0127 3	AR	MHANI038	1206843	0.708624	0.0019	0.000027	1440
9023-01-01	Down	UK 9 581713 2352 5	DO	MHANI039	1206844	0.708569	0.0018	0.000026	1440
9023-01-02	Fermanagh	UK 9 452262 2911 4	FE	MHANI040	1206845	0.707605	0.0021	0.000030	1440
9023-03-02	Armagh	UK 9 300855 0372 4	AR	MHANI050	1206846	0.708708	0.0023	0.000033	1440
					2015-21673				
9023-11-01	Londonderry	UK 9 560830 1521 6	LD	MHANI029	1208176R	0.708547	0.0032	0.000045	1460

Sample Reference No	County	cattle passport	County of last holding	IGFS ID	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
9023-11-02	Tyrone	UK 9 610713 2191 1	TY	MHANI030	1208177RRR	0.708381	0.0033	0.000047	1468
9023-12-01	Down	UK 9 560439 0824 6	DO	MHANI033	1208178	0.708166	0.0026	0.000037	1450
9023-12-02	Fermanagh	UK 9 452262 2869 4	FE	MHANI034	1208179RR	0.707553	0.0025	0.000035	1466
9023-12-03	Londonderry	UK 9 244549 0624 5	LD	MHANI035	1208180RRR	0.708285	0.0024	0.000034	1474
9012-02-01	Londonderry	UK 9 183360 0255 6	LD	MHANI041	1208181R	0.708215	0.0030	0.000042	1466
9012-02-02	Tyrone	UK 9 633068 0762 2	TY	MHANI042	1208182	0.708477	0.0030	0.000043	1450
9023-02-01	Antrim	UK 9 121091 1895 6	AN	MHANI043	1208183	0.706770	0.0024	0.000034	1450
9023-02-02	Armagh	UK 9 184091 4797 3	AR	MHANI044	1208184RR	0.708305	0.0023	0.000033	1468
9023-02-03	Down	UK 9 241885 0608 1	DO	MHANI045	1208185RRR	0.708415	0.0020	0.000028	1474
9012-03-01	Fermanagh	UK 9 560103 3712 3	LD	MHANI046	1208186	0.707905	0.0034	0.000048	1456
9012-03-02	Londonderry	UK 9 561174 0550 5	TY	MHANI047	1208187RRR	0.707800	0.0029	0.000041	1476
9012-03-03	Tyrone	UK 9 063440 1017 7	FE	MHANI048	1208188R	0.708504	0.0029	0.000041	1466

BLIND SAMPLES

Fera number	Reference	JHI Sample ID	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE	Turret
		2015-21627				
S15-050194	Blind sample 1	1207459	0.707905	0.0021	0.000030	1442
S15-050195	Blind sample 2	1207460RR	0.708191	0.0022	0.000031	1464
S15-050196	Blind sample 3	1207461	0.708801	0.0020	0.000028	1442
S15-050197	Blind sample 4	1207462	0.708559	0.0018	0.000026	1442
S15-050198	Blind sample 5	1207463	0.708342	0.0035	0.000050	1442
S15-050199	Blind sample 6	1207464R	0.706198	0.0033	0.000047	1458
S15-050200	Blind sample 7	1207465R	0.708823	0.0023	0.000033	1458
S15-050201	Blind sample 8	1207466	0.709250	0.0030	0.000043	1442
S15-050202	Blind sample 9	1207467	0.708067	0.0026	0.000037	1442
S15-050203	Blind sample 10	1207468R	0.709196	0.0034	0.000048	1458
S15-050204	Blind sample 11	1207469	0.708292	0.0021	0.000030	1442
S15-050205	Blind sample 12	1207470	0.708190	0.0022	0.000031	1442
S15-050206	Blind sample 13	1207471	0.708849	0.0031	0.000044	1442
S15-050207	Blind sample 14	1207472	0.709783	0.0021	0.000030	1442
S15-050208	Blind sample 15	1207473	0.709074	0.0021	0.000030	1442

SRM987 CRM DATA

Turret	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE		Turret	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE		Turret	$^{87}Sr/^{86}Sr$	St.Err. (%)	±2 SE
1368	0.710237	0.0009	0.000013		1418	0.710227*	0.0009	0.000013		1450	0.710257	0.0009	0.000013
1368	0.710249	0.0008	0.000011		1418	0.710231	0.0008	0.000011		1450	0.710235	0.0010	0.000014
1370	0.710242	0.0008	0.000011		1420	0.710255	0.0010	0.000014		1456	0.710258	0.0010	0.000014
1370	0.710245	0.0010	0.000014		1420	0.710237	0.0009	0.000013		1456	0.710228*	0.0011	0.000016
1372	0.710238	0.0010	0.000014		1426	0.710251	0.0009	0.000013		1460	0.710247	0.0011	0.000016
1372	0.710238	0.0011	0.000016		1426	0.710245	0.0009	0.000013		1460	0.710255	0.0010	0.000014
1376	0.710203*	0.0009	0.000013		1428	0.710230	0.0010	0.000014		1464	0.710229*	0.0009	0.000013
1376	0.710237	0.0010	0.000014		1428	0.710240	0.0010	0.000014		1464	0.710247	0.0010	0.000014
1380	0.710251	0.0010	0.000014		1430	0.710237	0.0009	0.000013		1466	0.710241	0.0009	0.000013
1380	0.710257	0.0009	0.000013		1430	0.710241	0.0008	0.000011		1466	0.710244	0.0011	0.000016
1382	0.710245	0.0010	0.000014		1432	0.710252	0.0009	0.000013		1468	0.710235	0.0008	0.000011
1382	0.710254	0.0009	0.000013		1432	0.710253	0.0009	0.000013		1468	0.710243	0.0010	0.000014
1388	0.710263	0.0010	0.000014		1434	0.710245	0.0009	0.000013		1474	0.710256	0.0011	0.000016
1388	0.710233	0.0010	0.000014		1434	0.710232	0.0010	0.000014		1474	0.710247	0.0009	0.000013
1390	0.710236	0.0011	0.000016		1436	0.710257	0.0009	0.000013		1476	0.710249	0.0010	0.000014
1390	0.710242	0.0011	0.000016		1436	0.710234	0.0009	0.000013		1476	0.710233	0.0010	0.000014
1400	0.710240	0.0008	0.000011		1438	0.710242	0.0010	0.000014					
1400	0.710248	0.0009	0.000013		1438	0.710238	0.0011	0.000016					
1402	0.710237	0.0009	0.000013		1440	0.710255	0.0008	0.000011					
1402	0.710245	0.0010	0.000014		1440	0.710241	0.0010	0.000014					
1406	0.710238	0.0010	0.000014		1442	0.710241	0.0009	0.000013					
1406	0.710239	0.0009	0.000013		1442	0.710235	0.0009	0.000013					
1410	0.710224*	0.0009	0.000013		1444	0.710245	0.0009	0.000013					
1410	0.710236	0.0009	0.000013		1444	0.710250	0.0009	0.000013					
1412	0.710265	0.0023	0.000033		1446	0.710222*	0.0009	0.000013					
1412	0.710234	0.0010	0.000014		1446	0.710246	0.0009	0.000013					
1416	0.710258	0.0010	0.000014		1448	0.710255	0.0010	0.000014					
1416	0.710226*	0.0009	0.000013		1448	0.710238	0.0009	0.000013					

*In house 2S QC failure on the in-house assigned value of 0.71025± 0.000022 (2SD). CRM certificate $^{87}Sr/^{86}Sr$ =0.71034±0.00026

FULL PROCEDURE BLANKS

Date	ng Strontium	Turret number
12/02/2015	0.54	1372
12/02/2015	7.26	1372
18/02/2015	0.58	1374
18/02/2015	0.46	1374
20/03/2015	0.36	1390
20/03/2015	0.11	1390
01/05/2015	2.80	1412
01/05/2015	0.40	1412
01/05/2015	1.01	1412
05/05/2015	0.33	1414
05/05/2015	3.63	1414
05/05/2015	0.51	1414
21/07/2015	1.63	1460
21/07/2015	5.81	1460
21/07/2015	1.10	1460
21/07/2015	1.23	1460
21/07/2015	2.07	1460
30/07/2015	0.99	1466
30/07/2015	5.52	1466
30/07/2015	1.11	1466

Discussion on Results

When comparing the results of BBOP II 2014-2015 data (Scotland & NI) – this study, to previous UK beef data it is apparent that there is some discord where the 2014-2015 data has a much smaller range (Figure 2). In order to investigate possible sources of the difference a full vertical audit of the process was undertaken.

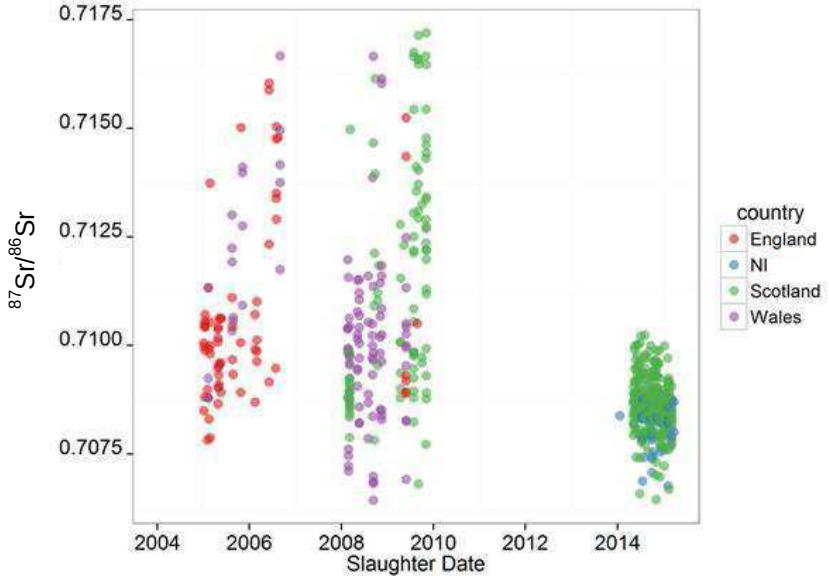

Figure 2. Comparison of BBOP II (>2014 data) to previous BBOP data.

Questions	Discussion	Conclusion
Where does the ratio come from?	The $^{87}Sr/^{86}Sr$ ratio should represent the local geology but there are several unknown influences in bovine Sr ratios. Rummel *et al.* (2012) states that most animals are fed partly on industrial fodder which may have a Sr ratio value which is similar to the modern seawater value, and not the local value. This, and the marine influence on coastal areas (Evans *et al.* 2010) may cause variation from expected. In addition additives to feedstuff or supplements provided may also skew the ratios. Bovines consume large volumes of water daily and this may reflect the rainfall or local reservoir ratio. Although bovines consume soil whilst grazing, whether their stomachs are able to digest the mineral Sr component is unsure – beyond the scope of this study.	Possible mixing of ratios with a global marine & feedstuff average of $^{87}Sr/^{86}Sr$ = 0.7092
Which part of the meat is taken for analysis?	The original report states that the English samples were neck or "other" meat. There is no reference to which part of the animal the Welsh or Scottish beef came from. Rummel *et al*. (2012) states that it is possible to get different ratios from one animal as different tissues have different turnover rates. Even small parts of bone (non-visible and high Sr content) could significantly influence the Sr ratio.	Possible bone contamination in previous studies producing a wider spread of data.
Contamination in the freeze drying and milling?	Despite the visual differences in the samples prepared on either site there was no grouping from where the samples were prepared. If there was contamination there would be more variation in the data not less.	No contamination from the freeze drying and milling
Has the muffle fractionated the Sr?	We showed during method development that the as the sample was heated in the muffle to a higher temperature it appeared to show slight fractionation of the Sr ratio (Figure 3). If this were to happen to real samples (i.e. muffle thermostat breaking down) the ratios would have an increased spread to a higher ratio and not group together at a lower ratio.	Not an issue with the muffle.
Is there a blank issue with the sample preparation?	This study produced full procedure blanks ranging from 0.11ng Sr to 7.26ng Sr. Plotting a two component mixing curve assuming an extreme ratio for the blank shows that only samples with an extremely low Sr concentration and worst case scenario blank may be influenced. More typically the blank has a <1% influence on the sample. When developing the method some of the trials had very high blank concentrations. In these cases the ratio tended to be higher with a higher blank (and lower with a low blank), figure 4.	The blank may influence one or two very extreme cases but not the typical concentration range of these samples. Any constant large contamination by blank would produce a data range more variable rather than less, reflecting the variability in concentrations of the individual samples.
Has there been an issue with the TIMS	The international certified reference material (CRM) SRM987 is run with every batch of samples through the instrument. Any issue with the instrument would be picked up with this	Not the instrument

Questions	Discussion	Conclusion
instrument?	data. There was no change with the SRM987 data throughout this project and we match the general consensus of the ratio value (including the certificate, 1982) – see figure 1. During the period of this study the instrument also ran unrelated samples which had Sr ratios ranging from 0.709 to 0.73 indicating that the instrument was clearly capable of detecting ratios above 0.710.	
Has there been any Rb contamination in the analysis	Each of the samples was put through ion exchange columns prior to analysis, and the instrument program was designed to burn off any trace of Rb remaining prior to analysis. The Rb was monitored throughout the sample analysis and if it looked slightly high the sample was repeated including preparation. Single sample comparisons between the most Rb contaminated run and the final uncontaminated run indicated that they were in the same scale of magnitude as the final ±2SE. There was no definitive trend of any Rb contamination effect on the Sr ratio. If there was any contamination by Rb the variability of Sr ratios would be greater rather than lesser.	This is unlikely to be the cause.

An additional piece of evidence which suggests the smaller range in $^{87}Sr/^{86}Sr$ observed currently was not due to any blank, contamination or instrument issues was that the value obtained for the NRC/CNRC RM8414 (bovine muscle powder) at 0.713057 which is substantially higher than the current BBOP II 2014-2015 data. This implies that if any current beef samples actually had values as high as 0.713 it would have been detected.

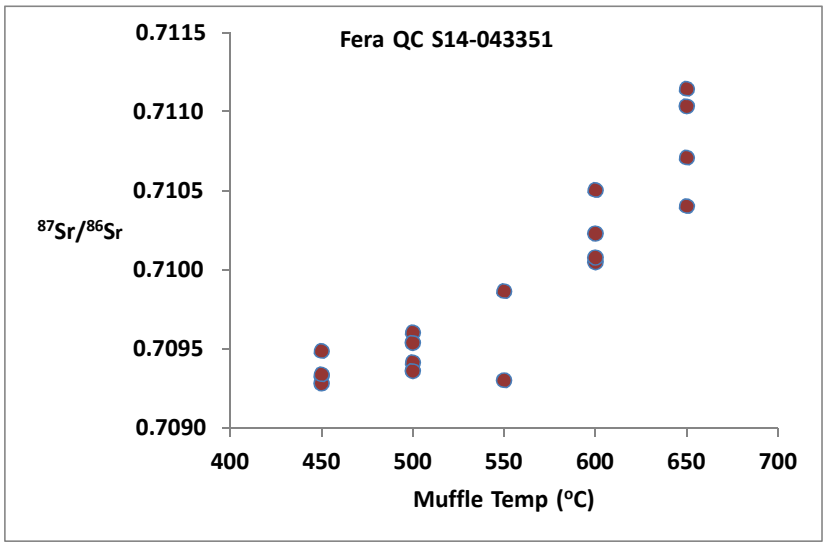

Figure 3. Sr ratios of same sample over a muffle temperature range.

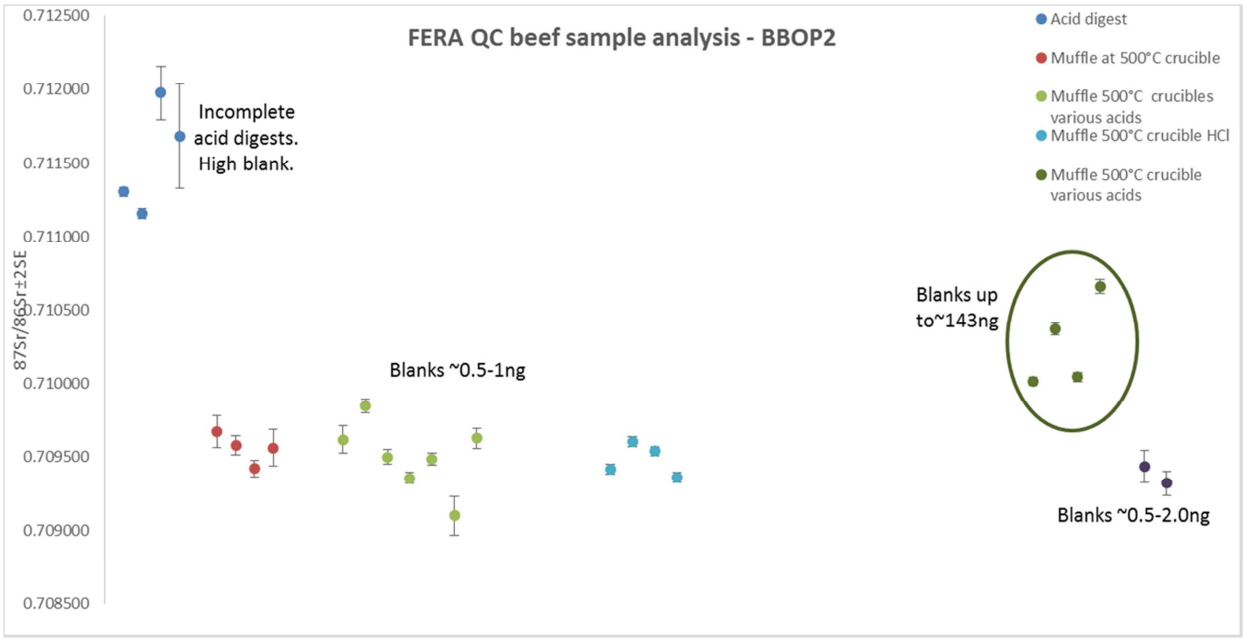

Figure 4. Method development showing high blanks producing raised ratios.

Conclusion on Results

From Figure 2 it is apparent that it is difficult to reconcile the data from this current (narrow range), with the previous UK beef origin project (wider range). The vertical audit undertaken allowed us to dismiss blank, contamination and instrument faults as being responsible for the observed Sr isotope distribution of the current data.

It is worth pointing out that the tight $^{87}Sr/^{86}Sr$ data of 0.707 -0.710 observed for beef tissue in BBOP II is not unique, Franke *et al.* (2008) observed $^{87}Sr/^{86}Sr$ values of 0.709-0.710 for beef from Austria, USA, Canada, Australia and Switzerland.

REFERENCES

Evans J.A., Montgomery, J., Wildman, G., & Boulton, N. (2010), *Journal of the Geological Society, London*, **167,** 1-4

Franke B.M., Koslitz, S., Micaux, F., Piantini, U., Maury, V., Pfammatter, E., Wunderli, S., Gremaud, G., Bosset, J-O., Hadorn, R. & Kreuzer, M. (2008) *Eur Food Res Technol* **226:** 761-769

Rummel S., Dekant, C.H., Hölzl, S., Kelly, S.D., Baxter, M., Marigheto, N., Quetel, C.R., Larcher, R., Nicolini, G., Fröschl. H., Ueckermann, H., & Hoogewerff, J. (2012) *Anal Bioanal Chem,* **402,** 2837-2848