The chemical composition of urinary calculi from Montana range steers and Pakistan buffalo and cattle
by Hung Chen Dang

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Chemistry
Montana State University


Abstract:
An investigation was made to determine the chemical composition of thirty-one urinary calculi from range steers and twenty urinary calculi from buffalo.

The stone samples were analyzed for percentages of moisture, volatile materials ash, total nitrogen, 'Silica, calcium, magnesium , potassium, SOdium, aluminum, iron, carbon dioxide, phosphates, Oxalate5 amino acid nitrogen, ammonium nitrogen, hexosamine, uric acid, and protein. ' - - ' , Quantitative analyses of the stones from range steers revealed the universal occurrence of protein and silica* Frequently associated, more or less, were calcium and oxalate. The variation of silica was between 11.5% to 76.1%, the average being 51.9%» ! In contrasts the stones of buffalo from West Pakistan were mainly calcium and carbonate, frequently associated with magnesium and phosphate*.- ' ,

# THE CHEMICAL COMPOSITION
# OF
# URINARY CALCULI FROM MONTANA RANGE STEERS AND PAKISTAN BUFFALO AND CATTLE

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at

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Approved

Head, Major Department

Chairman, Examining Committee

Dean, Graduate Division

Bozeman, Montana
December, 1958

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# I. ABSTRACT

An investigation was made to determine the chemical composition of thirty-one urinary calculi from range steers and twenty urinary calculi from buffalo.

The stone samples were analyzed for percentages of moisture, volatile material, ash, total nitrogen, silica, calcium, magnesium, potassium, sodium, aluminum, iron, carbon dioxide, phosphates, oxalate, amino acid nitrogen, ammonium nitrogen, hexosamine, uric acid, and protein.

Quantitative analyses of the stones from range steers revealed the universal occurrence of protein and silica. Frequently associated, more or less, were calcium and oxalate. The variation of silica was between 11.5% to 76.1%, the average being 51.9%.

In contrast, the stones of buffalo from West Pakistan were mainly calcium and carbonate, frequently associated with magnesium and phosphate.

## II. INTRODUCTION

One of the more troublesome problems which face the cattleman is urolithiasis, or urinary calculi, or commonly termed, "water belly." Economic losses of sheep and cattle, particularly range steers, because of this condition reach significant figures every year, especially during the fall and winter when the disease is more prevalent.

The fact is that urinary calculi are almost universal over the world, though some areas are seriously affected and some are not, and this problem is not only in their occurrence among the cattle and sheep, but also other sorts of animals.

The etiological factor of urinary calculus formation and prevention in cattle has been the object of a great deal of study. The subject is still remarkably confused. Many factors are related to the problem. According to the review of Newsom(1), various contributing causes have been indicated: diets containing large amounts of calcium, magnesium, oxalate, phosphate and silicon; mineral imbalance; vitamin A deficiency, hard and alkaline waters; bacterial infection of the genito-urinary tract; urinary irritation; hyperparathyroidism; and diseases of bones. Numerous theories, such as improper pH of the urine, colloidal constituents of the urine, and nuclei for stone formation in the urine have been advanced and experiments have been performed in attempts to determine the causes of urethral calculi in cattle. However, nothing seems to be consistent among outbreaks. Up until comparatively recent times, little has been done to determine the causes of calculi among range steers. Undoubtedly the cause is multiple.

To solve this problem, many suggestions have been made. However, the knowledge of urinary calculi of cattle is not complete, and no sufficient clinical data seem to be at hand to determine the extent to which various therapeutic procedures are successful. To prevent the formation of calculi, maintenance of a large water intake and output, feeding low ash diets with adequate vitamin A and protein, keeping the urine acid, eradication of infection from the urinary tract, and correction of metabolic diseases should be considered. The physical and chemical study of the urine and calculi may play one of the important roles in determining the etiology of a stone and may provide a guide to management and therapy.

The purpose of this paper is to quantitatively determine the constituents of urinary calculi of range steers and of buffaloes for the purpose of having a basis for further studies on their formation and prevention.

## III. REVIEW OF LITERATURE

As early as 1899, Klimmer (2) made a general mention of the chemical constitution of urinary calculi of domesticated animals, and Law (3), in 1908, discussed in a Bureau of Animal Industry report, the problem of calculi in cattle. He classed the urinary calculi according to their locality, form, and chemical composition, namely, coralline calculi, pearly calculi, green calculi, white calculi, ammonium magnesium calculi, silicious calculi, oxalate of lime calculi, and pultaceous deposits. The first four types mainly contain the carbonate of lime with some carbonate of magnesia; the fifth type is composed of ammonia-magnesium phosphate chiefly; the sixth type contains silica; the seventh type is formed of oxalate of lime; and the last type is the pultaceous deposits, and no chemical composition was mentioned.

In 1910, Michael (4) analyzed a urinary calculus from a shorthorn bull and found the substance most contained was calcium phosphate.

By examining the kidney stones from a cow fed alkali water, Larsen and Baily (4), 1913, reported the composition was moisture 2.8%, organic matter 15.8%, silica 76.9%, Ca 0.08%, Mg 0.05%, and Fe 0.006%. But they noted that the alkali water contained practically no silica.

In a study of calculi in cattle, Blount (6), 1931, mentioned seven types of calculi. They were composed of silicates, calcium and magnesium carbonate, calcium oxalate, calcium and magnesium phosphates, and iron carbonate.

Ranganathan (7), 1931, in India, analyzed twenty-three urinary calculi obtained from cattle. Twenty-one were vesical and urethral stones and two were renal. He found the average chemical composition was moisture 3.1%, total nitrogen 0.4%, $P_2O_5$ 0.9%, CaO 44.0%, MgO 4.8%, $CO_2$ 39.1%, and no uric acid. In the same year, Rangnanathan (18) reported a few types of bovine calculi. These stones were largely nitrogen and phosphate but no carbon dioxide.

Woodruff (9), 1934, in discussing the incidence of urinary calculi in feedlot cattle, stated that the urinary calculi are usually composed of calcium oxalate or calcium phosphate and uric acid.

In 1935, Aston (10) reported two cases of calculi in New Zealnd. One was chiefly magnesium-ammonium phosphate and the other was silica, calcium carbonate, calcium phosphate, and cystine.

Newsom (1), 1938, discussing the cause of calculi with reference to cattle and sheep, indicated that bovine urinary calculi are composed of calcium, magnesium, and aluminum salts of phosphoric acid.

Beeson, Pence, and Holm (11), 1943, reported the chemical composition of four stones from sheep, and showed loss on ignition 17-19%, silica 70-78%, calcium 0-1%, magnesium 0-1%, iron 0-1.42%, and no phosphate.

It is interesting that in 1947, Aldrich (12) mentioned a rare renal calculus in a calf, two months of age. The kidneys were enlarged, and the medullary portions were filled with a white chalky precipitate which was ammonium and sodium urate. It was thought probably to result in the young animal from the decomposition of the nucleoproteins of the nucleated fetal red corpuscles.

Black, Ellis, and Jones (13), 1947, studying the effect of limestone on the formation of urinary calculi in steers, found that the calculi disorder was aggravated by the feeding of grain sorghum, but no composition of the stones was mentioned.

Hill (14), 1950, mmentioned a case of urinary calculi in an aged bull with several hundred calculi in the urinary bladder. The urine showed by microscopic examination numerous triple phosphate, crystals, but no analyses were made.

Mathams and Sutherland (15), 1951, analyzed the calculi from four affected cows' kidneys. Two from one kidney were mulberry-shaped, hard, and brownish-black. From two other kidneys, they obtained fibrous, rather spongy, white to yellow calculi, each of which was composed almost entirely of silica, and in the fourth kidney there was a number of hard, angular, dull yellow calculi, consisting chiefly of silica, but containing a trace of calcium oxalate.

Swingle (16), 1953, studying the chemical composition of urinary calculi which came from 63 cases of occluding calculi in range steers, indicated that protein and silicon invariably were present, and in 20 cases, these were apparently the only components. Infrequently associated with these two components were calcium and oxalate and occasionally magnesium. Only rarely were ammonium carbonate and phosphate ions found.

In a study of the urinary calculi of sheep, Puntriano (17), 1955, indicated that they contained CaO 0.48% to 0.53%, $P_2O_5$ 0.74% to 0.82%, Mg 0.15%, $SiO_2$ 62% to 75.4%, and ash, 74% to 82%.

In 1956, Bennetts (18) indicated in the eastern districts of Western Australia, urinary calculi constitute a serious cause of mortality, frequently with losses of up to 10% in rams. The calculi were mostly silica and calcium carbonate.

In 1957 Sutherland (32), in Australia, reporting on urinary calculi in sheep, indicated that chemical analyses of calculi showed that they consisted chiefly of calcium carbonate (65% to 98%) with a varying amount of magnesium carbonate (up to 24%). In the discussion section of the same paper, Bennetts mentioned that silicious calculi are found principally in sheep living on cereals. The ash is about 90% silica, and there is very little organic matter. Young sheep are more susceptible, and on some properties, losses in weaner wethers may reach 30%.

## IV. MATERIALS AND METHODS

### A. Source of Stones

The calculi analyzed in this investigation were obtained from Dr. K. F. Swingle, Veterinary Research Laboratory, Montana State College. These stones were collected over the past few years by Swingle. Of the stones in this study, thirty-one calculi came from cases of occluding calculi among range steers in Montana and twenty calculi were from Dr. Abdussalam, College of Veterinary Medicine, State College of Washington, and were from buffalo and bullocks.

The source and description of each of the stones is listed in Table I and Table II.

TABLE I

The Source and Appearance of Urinary Calculi from Range Steers

| Serial No. | Accession # | Location (Organ) | Locality | Donor | Date of Collection | Color | Hardness | Size (mm.) | Shape |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2612 | urethra | Miles City | N.A. Jacobsen | 4/21/45 | | | | |
| 2 | 2695 | urethra | Beehive | Hertzler | 12/4/45 | | | | |
| 3 | 2711 | kidneys ureter bladder urethra | Ridge | J. Harris | 12/31/45 | | | | |
| 4 | 2721 | urethra | Powderville | D. Jones | 1/15/46 | gray | soft | 5 | mulberry |
| 5 | 2751 | urethra | Intake | J. Tomalino | 1/2/46 | brownish white | soft | 5 | mulberry |
| 6 | 2754-1 | urethra | Powderville | T. Bros. | 2/20/46 | brownish | soft | 5 | lobed |
| 7 | 2759 | urethra | Camp Creek, S. Dak. | J.B.Catron | 2/27/46 | brownish | soft | 3 x 6 x 6 | flat |
| 8 | 2761 | kidney | Olive | S. Memow | 3/4/46 | whitish | soft | 2 x 5 | chalky clips |
| 9 | 2780-1 | bladder | Canyon Creek | C. Johnson | 4/1/46 | grayish | soft | 5 x 11 | mulberry |
| 10 | 2780-2 | urethra | Canyon Creek | C. Johnson | 4/1/46 | grayish | soft | 1 to 5 | granules mulberry |
| 11 | 2902 | urethra | Malville | C.E.Crum | 1/8/47 | whitish | soft | 6 x 8 | irregular lump |
| 12 | 2904 | urethra | Melville | Tronrud | 1/10/47 | brownish | soft | 8 | mulberry |
| 13 | 2925 | urethra | Toston | E. Kimpton | 3/7/47 | brownish | soft | 5 | mulberry |

Table I Continued

| Serial No. | Accession # | Location (Organ) | Locality | Donor | Date of Collection | Color | Hardness | Size (mm.) | Shape |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 3180 | urethra | Forsyth | C. Holland | 12/31/47 | | | | |
| 15 | 3185 | kidney urethra bladder | Ennis | Newhall | 1/5/48 | | | | |
| 16 | 3187 | bladder & urethra | Ennis | Newhall | 1/10/48 | | | | |
| 17 | 3195-4 | urethra | Martinsdale | H. Pump | 1/17/48 | | | | |
| 18 | 3220 | urethra | Melville | C. Crum | 2/13/48 | | | | |
| 19 | 3696 | urethra | Camas | J. Welsh | 1/6/49 | | | | |
| 20 | 3670 | urethra | Gold Creek | Dutton | 12/21/48 | | | | |
| 21 | 3771 | urethra | Fish tail | Yates | 2/16/49 | | | | |
| 22 | 4093 | urethra | Stanford | Hughes Livestock Co. | 1/28/50 | | | | |
| 23 | 4134-1 | urethra | Glendive | C. C. Halver | 1/15/50 | | | | |
| 24 | 4205 | urethra | Billings | J. Kiichei | 3/17/50 | | | | |
| 25 | 4259 | urethra | Townsend | G. Gakisch | 3/2/45 | light brown | soft | 5 | mulberry |
| 26 | 2605-1 | urethra | ------ | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |
| 27 | 2605-2 | urethra | ------ | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |

Table I Continued

| Serial No. | Accession # | Location (Organ) | Locality | Donor | Date of Collection | Color | Hardness | Size (mm.) | Shape |
|---|---|---|---|---|---|---|---|---|---|
| 28 | 2605-3 | urethra | ~~W.H.Koper~~ | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |
| 29 | 2605-4 | urethra | -------- | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |
| 30 | 2605-5 | urethra | -------- | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |
| 31 | 2605-6 | urethra | -------- | W.H.Koper | 4/12/45 | brownish | soft | 3 | mulberry |

TABLE II

The Source and Appearance of Uroliths from West Pakistan

| Serial No. | Animal Species | Location (Organ) | Locality | Date of Collection | Color | Hardness | Size (mm.) | Shape |
|---|---|---|---|---|---|---|---|---|
| 1 | buffalo | kidney | Lahore | 1953 | grayish | hard | 6x9 | smooth surface, spherical |
| 2 | buffalo | kidney bladder | Lyallpur | 6/11/53 | yellowish | hard | 5x6 | smooth surface, spherical |
| 3 | bullock | bladder | Lahore | 8/24/53 | yellowish | hard | 5x5 | smooth surface, spherical |
| 4 | buffalo | kidney bladder | Lahore | 8/16/55 | grayish | hard | 5x3 | smooth surface, spherical |
| 5 | buffalo | kidney | Lahore | 1953 | grayish | hard | 9x13 | smooth surface, irregular |
| 6 | bullock | kidney | Lyallpur | 1953 | brownish | hard | 5x8 | spherical |
| 7 | buffalo | kidney bladder | Lahore | 8/7/53 | white | soft | --- | granule |
| 8 | bullock | bladder | Lahore | 2/8/53 | yellowish | hard | ~~2x3~~ | smooth surface, spherical |
| 9 | donkey | salivary duct | Choa-Saidenshah | 1953 | dull white | soft | --- | chalk-like |
| 10 | bullock | bladder | Lahore | 7/4/53 | yellowish | hard | --- | gravel |
| 11 | buffalo | bladder | Lahore | 1/20/55 | dull white | soft | --- | granule |
| 12 | buffalo | kidney | Lahore | 1953 | yellowish | hard | --- | granule |
| 13 | buffalo | urethra | Sheikhupura | 3/2/56 | yellowish | hard | 5x11 | smooth, spherical |

Table II Continued

| Serial No. | Animal Species | Location (Organ) | Locality | Date of Collection | Color | Hardness | Size (mm.) | Shape |
|---|---|---|---|---|---|---|---|---|
| 14 | buffalo | kidney | Lahore | 11/53 | yellowish | hard | --- | smooth, spherical |
| 15 | bullock | bladder | Lahore | 4/15/53 | yellowish | soft | 2 | spherical, pearl-like |
| 16 | bullock | bladder | Lahore | 43/8/53 | grayish | soft | 2 | spherical, pearl-like |
| 17 | bullock | bladder | Lahore | 2/8/53 | grayish | soft | 2 | spherical, pearl-like |
| 18 | bullock | bladder | Lahore | 4/8/53 | grayish | soft | 2 | spherical, pearl-like |
| 19 | buffalo | bladder | Lyallpur | 6/11/55 | grayish | soft | 2 | gravel |
| 20 | bullock | bladder | Lahore | 4/8/53 | grayish | soft | 2 | spherical, pearl-like |

B. Methods and Procedure

During the study of methods for determining the chemical composition of the calculi, the first considerations were the amount of samples and suitability of the methods. Some of the stones were quite small, so that it was very difficult to determine all of their composition.

The methods detailed in this paper were micro-methods and semi-micro-methods. Some procedures used in these analyses were developed and tested by Dr. Swingle, Biochemistry Section, Veterinary Research Laboratory of Montana State College.

In preparation for chemical analyses, each of the air-dried stones was ground to a very fine powder in a mullite mortar. The samples for each determination were weighed on a microbalance.

For the determination of moisture, volatile material, and ash, the powdered samples were weighed in a small platinum crucible and dried in a vacuum oven for one hour at 80°C. The loss in weight is reported as per cent moisture. After weighing the crucible which contained the dry sample was put in a muffle for an hour at 750°C.; the loss in weight represents volatile materials, and the residue is ash.

The total nitrogen determination of the stones was carried out by a modification of the micro-Kjeldahl steam distillation method of Rodgers and Harter (19). The sample was placed in a Kjeldahl flask of about 100 ml. capacity. A few drops of saturated copper sulfate and saturated potassium sulfate solution, followed by 5 ml. sulfuric acid (18 N), were added. The flask was heated with a small flame, then boiled at full heat until digestion was complete. After cooling, the solution was diluted to

10 ml. with water.

The flask containing the dissolved sample was attached to the distillation apparatus and 12 ml. of sodium hydroxide (10 N) was added slowly from the side tube without mixing the two layers. After attaching the receiver, the layers were mixed and distillate was collected in dilute sulfuric acid (0.01 N) for 10 minutes after the distillation started. Fifteen ml. of Nessler's reagent was added, and the solution was diluted to 50 ml. with distilled water. It was then mixed well and the transmittance measured at wave length 420 mμ in the Coleman spectrophotometer and the results compared with a standard curve.

Silicon was analyzed by the micro-method of Swingle (unpublished). Powdered stone (0.5 to 1.0 mg.) was mixed in a micro-platinum crucible with 0.5 ml. of an aqueous fusion solution containing 5 per cent potassium carbonate and 5 per cent sodium carbonate, evaporated to dryness under a heat lamp, then ignited for five minutes in a muffle at 750°C. After cooling, the crucible containing the fused mixture was filled about three-fourths full of water and set on a hot plate. The fused cake was taken up by adding 1 ml. of buffered acid molybdate solution and transferred to a 50 ml. volumetric flask. After development of the silicomylybdate and phosphomolybdate color, it was treated with 2 ml. of tartaric acid solution (10 %) to decolorize the phosphomolybdate and diluted to 50 ml. with water. Immediately after mixing the diluted solution, the optical density was measured at wave length 375 mμ. The concentration of silicon in the unknown was read by comparing its corrected optical density with a standard curve.

The calcium, magnesium, sodium, and potassium were determined by using the Beckman DU spectrophotometer with a hydrogen flame attachment (20). The standard was made up in solutions containing approximately the quantities of the components present in the stones.

The oxalate was analyzed for according to Brown (21). The stone powder was treated with sulfuric acid, heated, and titrated with standard potassium permangante at 60-80°C.

The carbon dioxide determination was carried out by a micro-method using the Warburg equipment. One milligram of sample was weighed into the Warburg's flask and 2.8 ml. of water added. In the side chamber was put 0.2 ml. of 1 M lactic acid. The apparatus was equilibrated in a water bath at constant temperature, then the lactic acid was tipped into the sample. From the final constant reading of the manometer, the carbon dioxide was calculated by correcting for pressure, temperature, and volume of the flask.

The alpha-amino acid nitrogen was determined by the ninhydrin method according to Yemm and Cocking (22) and using glutamic acid as a standard. In this procedure, the proline and hydroxyproline were not determined.

Phosphorus was analyzed according to the ascorbic acid method of Chen, Toribara, and Warner (23). The presence of arsenate interfered in this determination. Eight micrograms of arsenic are equivalent to 1 microgram of phosphorus, but in these samples of calculi, arsenic was absent. According to the author, silicate in amounts up to one milligram has no effect.

Iron analyses were carried out by the 2,2'-dipyridyl method of

Bothwell and Mallett (24). The error in measurement may be relatively greater with low concentrations of iron, but this method was sensitive enough to allow for moderate accuracy of 0.05 to 0.50 per cent.

Aluminum was determined according to Banerjee (25) by an aluminon method. Using the recommended procedure from 0.02 to 1 per cent aluminum could be determined.

The ammonia nitrogen was analyzed by a modified microdiffusion method according to Mayer, Kelley, and Morton (25).

For determination of hexosamine, the stones were hydrolyzed with hydrochloric acid (3N) at 120°C. for 4 hours followed by removal of HCl in a vacuum dessicator. The analyses were carried out with the modified Elson-Morgan method of Winzler (26), and also checked with the acetic anhydride method of Roseman and Daffner (27). Due to the effects of many factors, such as temperature, heating time, concentration, pH, and constitution of stones, the results of this determination were found to be highly variable and the results may be in error.

The method for determination of uric acid was that of Norton (28). It is based upon the reaction with arsenophosphotungstic acid reagent in the presence of cyanide ion.

For analysis of sulfur, the stone powder was heated with fuming nitric acid and precipitated with dilute barium chloride. After centrifuging, it was compared turbidimetrically with the known standards. Because of limited size of the samples the sulfur content may not be accurately determinable.

Zinc and lead were detected by the method with dithizone and resorcinal according to Feigl (29).

Proteins were detected by the method of Swingle (46). The per cent protein used in the calculation was obtained by subtracting the non-protein nitrogen from the total nitrogen and multiplying by the factor 6.25.

For determination of density of stones, they were weighed in air and in water and calculated by the following formula:

$$d = \frac{W_{air}}{W_{air} - W_{water}}$$

## V. Experimental Results

In these experiments, two series of urinary calculi were analyzed--one was from range steers and the other was from buffalo. The results can be seen in Table III and Table IV. In these two tables, it is very clear that the compositions of the stones can be grouped into two different kinds. Steer stones mainly consisted of silicon and protein, associated more or less with calcium and oxalate, while the buffalo stones mainly consisted of calcium, carbonate, and magnesium.

There were silicon and protein in every steer stone. The quantity of $SiO_2$ ranged from 11.5 per cent to 76.1 per cent, the average being 52.8 per cent. These distributions are listed in Table V. Stones with 40 per cent of $SiO_2$ included about 80 per cent of all stones tested, and 61 per cent of the stones had 50 per cent or more of $SiO_2$.

Table V

Distribution of Silica Levels Among Calculi

| Range of Silica % | No. of Stones | Percentage of Total Steer Stones |
|---|---|---|
| 10 - 20 | 3 | 10 |
| 20 - 30 | 1 | 3 |
| 30 - 40 | 2 | 6 |
| 40 - 50 | 6 | 19 |
| 50 - 60 | 7 | 23 |
| 60 - 70 | 6 | 19 |
| 70 - 80 | 6 | 19 |

## TABLE III

The Chemical Composition of Urinary Calculi from Range Steers
(As percentages of air-dry samples)

| Stone No. | Moisture | Volatile | Ash | Total Nitrogen | $SiO_2$ | CaO | MgO | $Na_2O$ | $K_2O$ | $CO_2$ | $P_2O_5$ | $Fe_2O_3$ | $Al_2O_3$ | Oxalate $C_2O_3$ | $NH_3$ | Amino-N | Hexosamine | $SO_3$ | Uric acid | ZnO | PbO | Protein | Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2612 | 1.96 | 26.55 | 71.49 | 1.69 | 63.81 | 4.09 | 0.00 | 0.34 | 0.64 | 0.00 | 0.46 | 0.04 | 0.00 | 6.13 | 0.00 | 0.72 | 2.64 | trace | 0.00 | 0.00 | 0.00 | 10.56 | 88.03 |
| 2695 | 1.79 | 37.33 | 60.88 | 1.54 | 44.30 | 14.89 | 0.36 | 0.47 | 0.36 | 0.96 | 0.43 | 0.00 | 0.22 | 21.32 | 0.00 | 0.40 | 2.35 | 0.00 | 0.00 | 0.00 | 0.00 | 9.63 | 94.73 |
| 2711 | 2112 | 23.51 | 74.37 | 2.46 | 68.56 | 2.13 | 0.42 | 1.55 | 0.64 | 0.00 | 0.45 | 0.06 | 0.00 | 2.83 | 0.00 | 0.87 | 2.19 | 0.00 | 0.00 | 0.00 | 0.00 | 15.38 | 94.14 |
| 2721 | 2.42 | 37.00 | 60.58 | 1.63 | 37.82 | 17.37 | 0.43 | 0.38 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 21.07 | 0.00 | 0.75 | 2.15 | 0.00 | 0.00 | 0.00 | 0.00 | 10.19 | 89.92 |
| 2725 | 1.68 | 28.33 | 69.99 | 3.13 | 67.25 | 1.08 | 0.00 | 1.08 | 0.00 | 0.00 | 0.54 | 0.00 | 0.00 | 1.34 | 0.00 | 2.76 | 2.26 | 0.00 | 0.00 | 0.00 | 0.00 | 19.56 | 92.53 |
| 2754-1 | 1.57 | 45.99 | 52.47 | 1.79 | 26.29 | 22.30 | 0.81 | 0.17 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 31.91 | 0.00 | 0.39 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.19 | 94.29 |
| 2759 | 2.23 | 46.40 | 51.37 | 3.18 | 32.89 | 16.00 | 0.43 | 0.73 | 0.25 | 0.00 | 0.00 | 0.08 | 0.00 | 25.66 | 0.00 | 0.77 | 3.82 | 0.00 | 0.18 | 0.00 | 0.00 | 19.50 | 97.95 |
| 2761-1 | 1.71 | 31.10 | 67.19 | 2.73 | 49.27 | 17.01 | 0.00 | 0.47 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 8.20 | 0.00 | 0.85 | 3.60 | 0.00 | 0.00 | 0.00 | 0.00 | 17.06 | 94.09 |
| 2780-1 | 2.25 | 54.44 | 43.31 | 3.21 | 17.69 | 23.20 | 1.01 | 0.30 | 0.50 | 0.00 | 0.00 | 0.04 | 0.28 | 31.03 | 0.00 | 1.07 | 2.03 | 0.00 | 0.00 | 0.00 | 0.00 | 20.06 | 96.36 |
| 2780-2 | 2.46 | 58.19 | 39.35 | 4.71 | 16.13 | 18.55 | 1.47 | 0.48 | 0.47 | 4.19 | 0.29 | 0.00 | 0.00 | 23.12 | 0.00 | 1.69 | 1.75 | 0.00 | 0.00 | 0.00 | 0.00 | 29.50 | 96.66 |
| 2902 | 1.78 | 23.82 | 74.39 | 3.47 | 70.47 | 1.10 | 0.00 | 0.47 | 0.11 | 0.00 | 0.00 | 0.06 | 0.00 | 2.40 | 0.00 | 1.01 | 3.81 | 0.00 | 0.16 | 0.00 | 0.00 | 21.37 | 97.92 |
| 2904 | 1.99 | 36.75 | 61.26 | 1.89 | 47.73 | 6.89 | 0.56 | 4.82 | 0.44 | 0.00 | 1.03 | 0.00 | 0.10 | 11.68 | 0.00 | 1.02 | 4.59 | trace | 0.00 | 0.00 | 0.00 | 11.81 | 87.05 |
| 2925 | 1.93 | 35.45 | 62.62 | 2.66 | 49.87 | 11.15 | 0.22 | 0.36 | 0.27 | 0.00 | 0.00 | 0.00 | 0.16 | 10.36 | 0.00 | 1.03 | 3.58 | 0.00 | 0.26 | 0.00 | 0.00 | 16.19 | 90.77 |
| 3180 | 1.73 | 33.64 | 64.63 | 3.48 | 52.71 | 10.51 | 0.21 | 0.41 | 0.26 | 0.98 | 0.25 | 0.00 | 0.0004.000 | 4.56 | 0.00 | 1.00 | 3.24 | 0.00 | 0.18 | 0.00 | 0.00 | 21.37 | 93.26 |
| 3185 | 1.55 | 22.19 | 76.26 | 2.64 | 70.11 | 2.25 | 0.00 | 0.69 | 0.00 | 1.17 | 0.37 | 0.00 | 0.18 | 3.69 | 0.00 | 0.68 | 2.25 | 0.00 | 0.00 | 0.00 | 0.00 | 16.50 | 96.51 |
| 3187-2 | 1.18 | 18.15 | 80.67 | 2.38 | 72.96 | 1.15 | 0.75 | 0.99 | 0.90 | 1.99 | 0.00 | 0.07 | 0.00 | 1.40 | 0.00 | 0.63 | 2.05 | 0.00 | 0.00 | 0.00 | 0.00 | 14.87 | 96.56 |
| 3195-4 | 1.41 | 35.09 | 63.50 | 4.33 | 57.51 | 3.44 | 0.33 | 0.27 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 4.78 | 0.00 | 1.21 | 4.91 | 0.00 | 0.00 | 0.00 | 0.00 | 27.06 | 95.22 |
| 3220 | 1.10 | 37.31 | 61.58 | 3.34 | 50.24 | 8.58 | 0.32 | 0.26 | 0.15 | 4.66 | 0.00 | 0.00 | 0.00 | 11.05 | 0.00 | 0.64 | 2.08 | trace | 0.00 | 0.00 | 0.00 | 20.87 | 97.23 |
| 3696 | 1.44 | 34.18 | 64.38 | 2.64 | 53.63 | 7.83 | 1.14 | 0.69 | 0.14 | 1.19 | 0.28 | 0.00 | 0.20 | 8.22 | 0.00 | 0.95 | 2.84 | 0.00 | 0.00 | 0.00 | 0.00 | 16.50 | 93.99 |
| 3670 | 1.21 | 30.97 | 67.82 | 2.00 | 56.87 | 8.83 | 0.00 | 1.04 | 0.00 | 0.78 | 0.00 | 0.08 | 0.00 | 13.36 | 0.00 | 0.46 | 1.95 | trace | 0.00 | 0.00 | 0.00 | 12.50 | 94.67 |
| 3771 | 2.43 | 27.17 | 70.42 | 3.02 | 52.79 | 12.51 | 0.00 | 0.38 | 0.21 | 0.00 | 0.00 | 0.06 | 0.18 | 7.96 | 0.00 | 0.56 | 2.11 | 0.00 | 0.00 | 0.00 | 0.00 | 18.87 | 95.37 |
| 4093-1 | 2.25 | 30.06 | 67.69 | 2.22 | 59.39 | 4.24 | 0.35 | 0.57 | 0.00 | 1.73 | 0.37 | 0.00 | 0.20 | 9.75 | 0.00 | 0.98 | 3.54 | 0.00 | 0.00 | 0.00 | 0.00 | 13.87 | 92.56 |
| 4134-1 | 1.86 | 16.81 | 81.33 | 1.91 | 76.10 | 2.80 | 0.80 | 0.17 | 0.47 | 0.00 | 0.30 | 0.05 | 0.00 | 1.69 | 0.43 | 0.51 | 1.64 | 0.00 | 0.15 | 0.00 | 0.00 | 9.81 | 94.48 |
| 4205 | 1.91 | 26.25 | 71.84 | 2.20 | 60.52 | 9.02 | 0.00 | 0.78 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 2.96 | 0.00 | 1.87 | 3.55 | trace | 0.00 | 0.00 | 0.00 | 13.44 | 88.85 |
| 4259 | 2.29 | 39.07 | 58.64 | 1.86 | 46.93 | 8.60 | 0.37 | 0.64 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 11.82 | 0.00 | 0.88 | 2.94 | 0.00 | 0.00 | 0.00 | 0.00 | 11.63 | 82.70 |
| 2605-1 | 1.37 | 44.06 | 54.57 | 0.95 | 11.51 | 37.16 | 4.75 | 0.43 | 0.49 | 26.22 | 0.54 | 0.00 | 0.12 | 2.27 | 0.00 | 0.19 | 1.06 | —— | —— | 0.00 | 0.00 | 5.94 | 90.80 |
| 2605-2 | 2.02 | 32.90 | 65.08 | 1.76 | 61.18 | 0.96 | —— | 0.32 | 0.00 | 1.49 | —— | 0.00 | 0.00 | 1.08 | 0.00 | 0.43 | 2.74 | —— | —— | 0.00 | 0.00 | 11.00 | 78.05 |
| 2605-3 | 1.08 | 21.46 | 77.46 | 1.81 | 69.61 | 4.04 | 0.00 | 0.73 | 0.00 | 0.00 | 0.17 | 0.07 | 0.20 | 1.43 | 0.00 | 0.97 | 3.89 | —— | —— | —— | —— | 11.31 | 88.44 |
| 2605-4 | 1.95 | 23.01 | 75.04 | 1.85 | 70.23 | 3.37 | 0.00 | 1.01 | 0.00 | —— | 0.14 | 0.05 | —— | 3.14 | 0.00 | 0.71 | 3.64 | —— | —— | —— | —— | 11.56 | 91.45 |
| 2605-5 | 1.65 | 35.53 | 62.82 | 2.88 | 49.48 | 9.77 | —— | 0.33 | —— | —— | —— | —— | —— | 0.84 | —— | 0.75 | 2.68 | —— | —— | —— | —— | 18.00 | 82.95 |
| 2605-6 | 1.87 | 22.55 | 75.58 | 1.74 | 73.25 | —— | —— | —— | —— | —— | —— | —— | —— | 4.31 | —— | 0.85 | 2.82 | —— | —— | —— | —— | 10.87 | 90.30 |
| Average | 1.78 | 32.76 | 65.46 | 2.49 | 52.81 | 8.74 | 0.53 | 0.71 | 0.22 | 0.71 | 0.23 | | | | | | | | | | | | |

*Total is the sum of moisture, $SiO_2$, CaO, MgO, $Na_2O$, $K_2O$, $CO_2$, $P_2O_5$, $Fe_2O_3$, $Al_2O_3$, $C_2O_3$, $NH_3$, and protein.