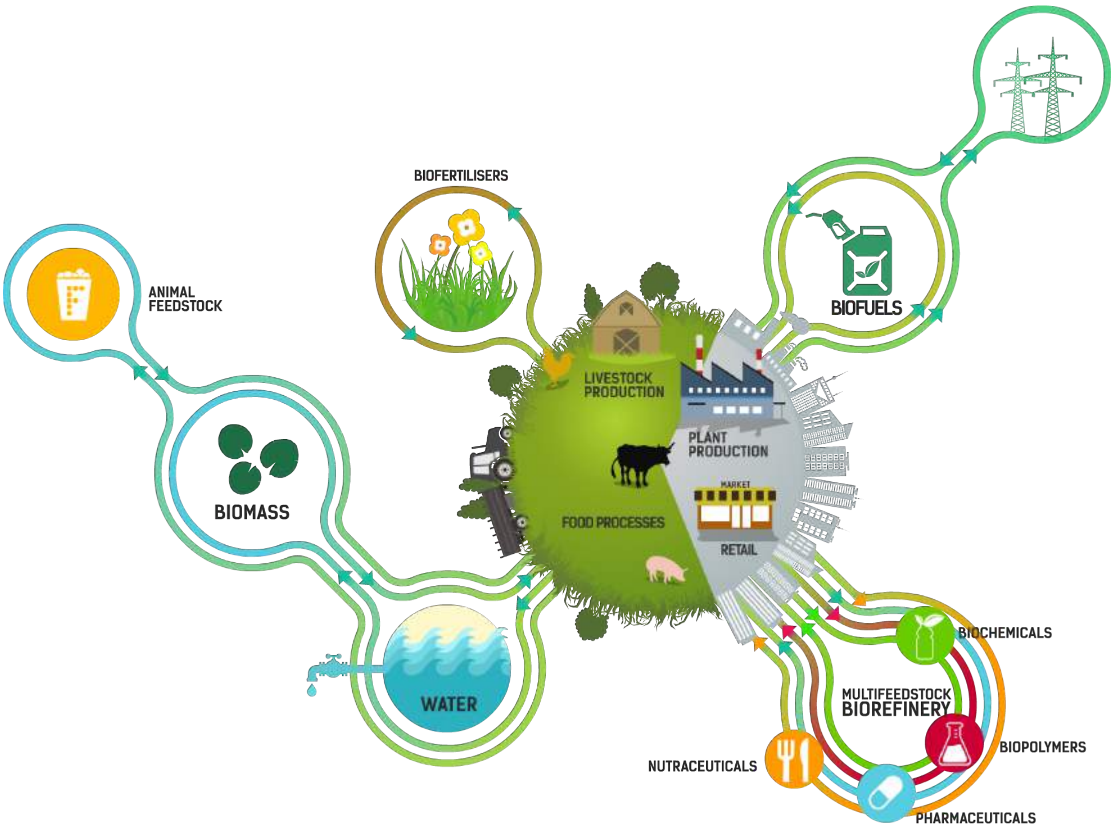
D1.5 Report on the main agricultural value chains in China and corresponding regulations



ACKNOWLEDGEMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement № 690142. Chinese partners are beneficiaries not in receipt of EU funding.

Deliverable Document Sheet	
Project Acronym	AgroCycle
Project Title	Sustainable techno-economic solutions for the agricultural value chain
Grant Agreement number	690142
Call identifier	H2020-WASTE-2015-two-stage
Topic identifier	WASTE-7-2015 Ensuring sustainable use of agricultural waste, co-products and by-products
Funding Scheme	Research and Innovation Action
Project duration	36 months (June 2016 – May 2019)
Coordinator	NUID UCD – Professor Shane Ward
Website	www.AgroCycle.eu
Deliverable No.	1.5
Deliverable title	Report on the main agricultural value chains in China and corresponding regulations
Description	The main agricultural value chain in China was investigated both in quantity and quality aspects. The annual outputs of agricultural waste and the application status in energy, roughage, fertilizer, material etc. on country basis were estimated. Based on nationally representative agricultural waste samples (5490 crop residues and 5314 animal manures) across China, the properties including compositional, proximate, ultimate, mineral elemental and heating values etc. were analysed and the statistical results were presented. Meanwhile, the regulations on AWCB in China were summarized.
WP No.	1
Related task	Tasks 1.1 - 1.5
Lead Beneficiary	CAU
Author(s)	*Lujia Han, Xian Liu, Zengling Yang, Longjia Chen, Guangqun Huang, Weihua Xiao*
Contributor(s)	*Binbin Dong, Xinlei Wang, Tianshu Chu*
Type	Report
Dissemination Level	Public
Language	English – GB
Due Date	31/12/2016
Submission Date	31/12/2016

Date:	Action:	Version:	Ownership:
16/10/2016	Written	V.1	*Lujia Han*
30/10/2016	Formatted	V.2	Konstantinos Kontogiannopoulos
17/11/2016	Checked	V.3	*Weihua Xiao*
31/12/2016	Submitted via Online Portal to Funding Agency	V.3	*Ger Hanley*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690142

Table of Contents

List of Tables

List of Figures

1. Specify types of crop residue and manure that would be included in the project

Five types of crop residues including corn stover, wheat straw, rice straw, cotton stalk, and rape straw and five types of animal manure including dairy manure, beef manure, pig manure, layer manure, and broiler manure, were investigated in this project.

2. Value chain analysis in quantity aspect: Summarize the information of annual output and application status in energy, roughage, fertilizer, material etc. on country basis

2.1 Annual output and application status of crop residues in China

According to Bi (2010) and China Statistical Yearbook (2015), the theoretical quantity of China's crop residue resources is shown in Table 1.

Estimates of crop residue production were made on the basis of the production of different crops in China (China Statistical Yearbook, 2015), and research information on the straw/grain ratio. As shown in Table 1, the total output of crop residues from all types of agricultural crops in mainland China in 2014 is 9.01×10^8 t.

Crop residue types mainly include wheat straw, rice straw, corn stover, cotton stalk, rape stalk and others. The total percentage of the five types of crop residues investigated in this project accounts for 74% of the national output as shown in Figure 1.

Table 1: Estimates of crop residue production in mainland China, 2014.

CROP TYPES	CROP YIELD ($\times 10^8$ T)	CROP RESIDUE	RATIO OF STRAW TO GRAIN	CROP RESIDUE YIELD ($\times 10^8$ T)
Wheat	1.26	Wheat Straw	1.3	1.64
Rice	2.07	Rice Straw	1.0	1.96
Corn	2.16	Corn Stover	1.1	2.37
Rapeseeds	0.15	Rape Stalk	2.7	0.40
Cotton	0.06	Cotton Stalk	5.0	0.31
Others	2.13	-	-	2.33
Total	7.82	-	-	9.01

The proportion of five different types of crop residues in 2014 is shown in Figure 1.

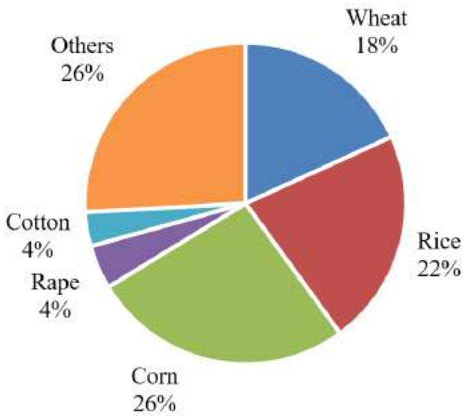


Figure 1: Percentage of five types of crop residues among total quantity in 2014.

According to the final evaluation on the crop residue utilisation during the 12th Five-Year Plan, major application status of crop residues is shown in Figure 2.

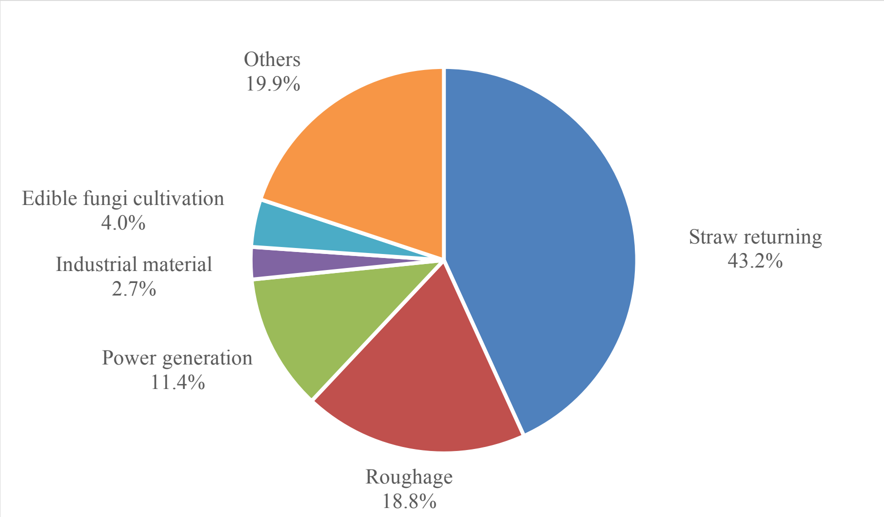


Figure 2: Main applications of crop residues in China during the 12th Five-Year Plan.

According to the final evaluation on crop residue utilisation during the 12th Five-Year Plan, the theoretical quantity, the collectable quantity, and the utilised quantity of China's crop residue resources in 2015 was 10.4×10^8 t, 9.0×10^8 t, and 7.2×10^8 t, respectively. Based on the collectable quantity, major application status of China's crop residue in 2015 is shown in Figure 2.

2.2 Annual output and application status of manure in China

According to the related statistic data in China Animal Husbandry and Veterinary Yearbook 2015 and China Poultry Industry Development Report 2014 and the excretion coefficient of different livestock and poultry (Lin et al., 2012), the production of major livestock and poultry manure in mainland China can be estimated as shown in Table 2.

Table 2: Estimates of livestock and poultry manure production in mainland China, 2014.

ANIMAL TYPES	ANIMAL NUMBERS ($\times10^4$)	EXCRETION COEFFICIENT	MANURE PRODUCTION ($\times10^8$T)
Hog	73510.4	3.08	4.42
Sow	4962.5	9.2	1.70
Layer	117000	0.11	0.50
Broiler	820900	0.14	0.82
Dairy Cattle	1499.1	37.15	1.97
Beef Cattle	9078.9	22.69	7.62
Working Cattle	2038	44.67	2.06
Horse	604.3	19.04	0.36
Donkey & Mule	807.2	16.58	0.40
Sheep	30314.9	2.38	2.64
Duck & Goose	423700	0.11	0.95
Rabbit	51679.1	0.11	0.05
Total	1536094.4	-	23.49

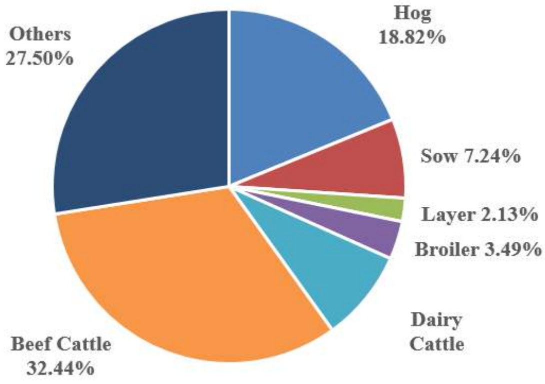


Figure 3: The proportions of livestock and poultry manure production in mainland China 2014.

It can be seen that the production of five types of manure (layer, broiler, dairy cattle, beef cattle, pig) was more than 70% of the total output of livestock and poultry manure. Therefore, these five types of manure were selected as the main research objects in our characterisation.

Zhu *et al*. (2014) predicted the future manure outputs in China and reckoned that it would reach 2.875 billion tons in 2020 and 3.743 billion tons in 2030 respectively as shown in Figure 4 and Figure 5 (Zhu & Ma, 2014).

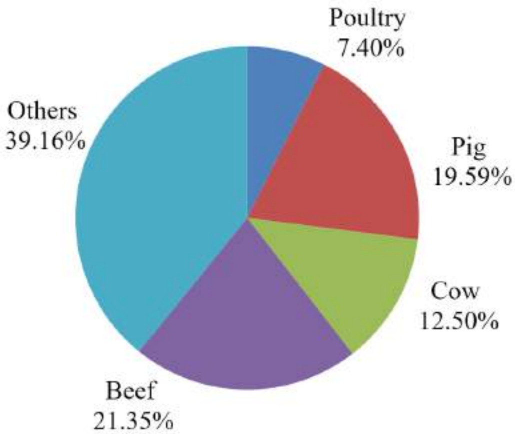


Figure 4: The proportions of manure production in mainland China in 2020 (Zhu & Ma, 2014).

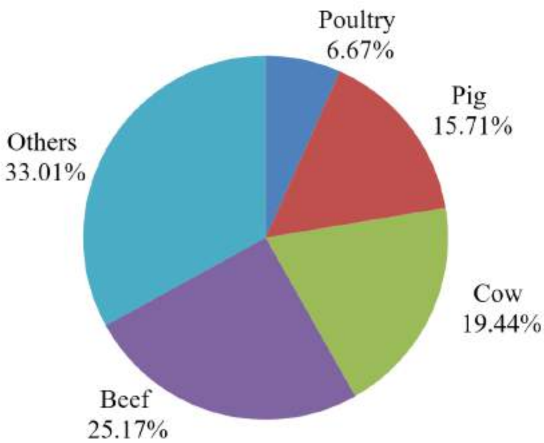


Figure 5: The proportions of manure production in mainland China in 2030 (Zhu & Ma, 2014).

Utilisation of livestock and poultry manure as a fertilizer for crops or trees has been a common practice in China. In recent years, the anaerobic fermentation for biogas production was also increasing. According to the literatures (Shan et al., 2007; Zhu et al., 2008) (Wang et al. 1994) livestock and poultry manure utilisation and proportions are shown in Figure 6.

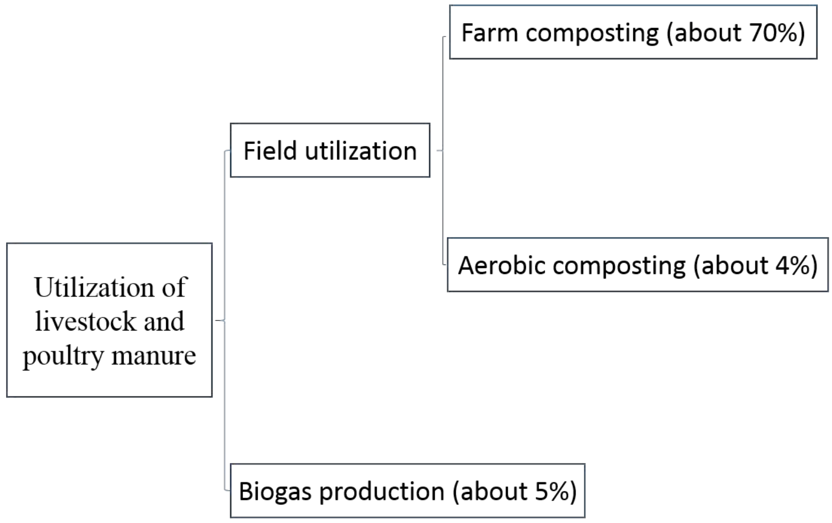


Figure 6: Main utilisation of animal manure.

3. Value chain analysis in quality aspect: Based on big representative samples extensively collected across different areas of China, characterising and analyzing their compositional properties relevant to different applications, including mechanical, chemical, proximate, ultimate, mineral elemental and HHV and LHV etc. Analyzing the potential for different application based on the characterisation results

3.1 Characterisation of crop residues in China

3.1.1 Materials and methods

3.1.1.1 Sample collection and preparation

According to the crop distribution across China, five types of crop residue samples were selected based on different species and locations. Wheat straw, rice straw, corn stover, rape stalk and cotton stalk samples were collected at the fully ripe stage during 2011-2014. Sampling was conducted at 326 sites in 31 provinces, cities, and autonomous regions in China. A total of 5490 samples were collected, including 1218 wheat straw samples, 1733 rice straw samples, 1799 corn stover samples, 490 rape stalk samples, and 250 cotton stalk samples. Each crop residue sample was taken from different plots in the field. The samples had the grains and roots removed and the middle part retained. Then, the samples were thoroughly mixed to obtain a representative batch of approximately 2 kg.

According to American Society for Testing and Materials (ASTM) E1757-01, the collected crop residue samples were dried in a convection oven at 45 °C for 48 h, and then milled through a 20 mesh sieve. Then, the samples were stored in bags prior to analysis.

3.1.1.2 Sample analysis

The analysis methods for composition, heating values, physical and thermal parameters of crop residue are listed in Table 3. Composition analysis consists of chemical composition, proximate analysis, ultimate analysis, and mineral elements.

Table 3: Analysis methods for crop residue properties.

	PARAMETER	ABBREVIATION	ANALYTICAL METHOD
Chemical	dry matter	DM	ASTM E1757—01 Standard practice for preparation of biomass for compositional analysis
	Cellulose	Cel	NREL/TP-510-42618 Determination of Structural Carbohydrates and Lignin in Biomass
	Hemicellulose	Hem	
	Lignin	Lig	NREL/TP-510-42618 Determination of Structural Carbohydrates and Lignin in Biomass
	water soluble carbohydrates	WSC	McDonald & Henderson (1964). Determination of Water-Soluble Carbohydrates in Grass, J. Sci. Food Agric
	crude protein	CP	AOAC Official Method 2001.11 Protein (Crude) in Animal Feed
	neutral detergent fiber	NDF	GB-T 20806-2006 Determination of Neutral Detergent Fiber in Feedstuffs
	acid detergent fiber	ADF	AOAC 973.18 Fiber (Acid Detergent) and Lignin (H2SO4) in Animal Feed
Proximate	moisture	Moist	ASTM E1756-08 Standard Test Method for Determination of Total Solids in Biomass
	volatile matter	VM	ASTM E872-82(2006) Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels
	Ash	Ash	ASTM E1755-01(2007) Standard Test Method for Ash in Biomass
	fixed carbon	FC	ASTM E 870-82 Standard Test Method for Analysis of Wood Fuels
Ultimate	C, H, N, S, O	C, H, N, S, O	ASTM E777 -08 Standard Test Method for Carbon and Hydrogen in the Analysis Sample of refuse-Derived Fuel
			ASTM E870-82(2006) Standard Test Methods for Analysis of Wood Fuels
Mineral	P, K	P, K	AOAC Official Method 975.03 Metals in Plants and Pet Foods
			Method of determination of P, K, Ca, Mg and trace elements (John L. Kovar)
Heating Value	higher heating value	HHV	ASTM E711-87 Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter
	Lower heating value	LHV	
Physical & thermal	specific heat capacity	SHC	ASTM E1269-05 Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
	Thermal conductivity	TC	GB-T 10297-1998 Test Method for Thermal Conductivity of Nonmetal Solid Materials by Hot-wire Method

3.1.1.3 Data processing and analysis

Excel 2013、SPSS 20、OriginPro 8.5 software were used to process and analyse data. Firstly, data was prepared in Excel 2013. Then, statistical analysis was conducted using SPSS 20. Data outlier was defined based on 1.5IQR (interquartile range) rule and thus excluded. Scheffe rule was selected for analysis of variance in SPSS 20. Finally, boxplot of each parameter was obtained using OriginPro 8.5.

3.1.2 Results

Table 4 shows the results of chemical composition, proximate analysis, ultimate analysis, mineral elements, heating values, physical and thermal parameters. It indicated that there are significant differences among the five types of crop residues in general.

Table 4: Compositional and property analysis statistical results of crop residue.

PROPERTIES		WHEAT	RICE	CORN	RAPE	COTTON	TOTAL
Chemical	DM (%)	94.61±2.62^{b}	93.67±2.79^{a}	93.24±3.23^{a}	95.52±3.62^{c}	96.21±1.85^{d}	93.96±3.10
	Cel (% DM)	38.95±4.68^{b}	35.94±4.73^{a}	38.64±5.82^{b}	38.98±6.79^{b}	38.84±4.55^{b}	37.90±5.46
	Hem (% DM)	22.61±5.53^{d}	22.60±7.46^{d}	20.47±6.79^{c}	16.53±3.75^{b}	12.70±2.43^{a}	20.96±6.87
	Lig (% DM)	20.68±2.92^{d}	13.30±5.88^{a}	17.58±5.98^{c}	15.09±4.89^{b}	22.03±7.08^{e}	16.76±6.19
	WSC (% DM)	2.39±1.38^{a}	2.83±1.87^{b}	4.12±2.43^{c}	2.34±1.55^{a}	2.53±1.32^{ab}	3.12±2.08
	CP (% DM)	4.38±1.38^{a}	4.86±1.44^{b}	5.08±1.40^{b}	4.20±1.46^{a}	5.77±1.90^{c}	4.81±1.49
	NDF (% DM)	73.09±6.83^{c}	68.01±4.93^{a}	68.89±5.99^{a}	70.79±5.25^{b}	71.24±7.32^{b}	69.86±6.22
	ADF (% DM)	48.06±5.20^{c}	44.05±5.95^{a}	45.24±5.28^{b}	52.04±7.29^{d}	56.87±6.27^{e}	46.62±6.58
Proximate	Moist (% DM)	4.64±1.74^{a}	5.38±2.42^{b}	5.14±1.47^{b}	5.35±1.97^{b}	4.65±2.17^{a}	5.10±1.96
	VM (% DM)	68.64±3.80^{b}	66.73±3.28^{a}	70.75±3.50^{c}	72.90±3.67^{e}	71.67±2.47^{d}	69.25±4.04
	Ash (% DM)	8.95±1.80^{d}	13.29±2.47^{e}	6.66±2.00^{b}	7.30±2.03^{c}	5.24±1.85^{a}	9.20±3.57
	FC (% DM)	17.88±3.20^{c}	14.74±2.41^{a}	16.95±3.67^{b}	14.33±3.93^{a}	18.27±2.14^{c}	16.28±3.48
Ultimate	C (% DM)	42.05±1.32^{b}	38.82±2.70^{a}	41.95±2.13^{b}	41.75±2.59^{b}	44.26±2.73^{c}	41.08±2.77
	H (% DM)	5.72±0.56^{b}	5.58±0.78^{a}	5.79±0.62^{b}	6.37±1.08^{c}	5.81±0.69^{b}	5.77±0.75
	N (% DM)	0.68±0.17^{a}	0.99±0.33^{c}	1.04±0.37^{c}	0.93±0.49^{b}	1.13±0.26^{d}	0.94±0.36
	S (% DM)	0.49±0.21^{b}	0.992±0.31^{b}	0.61±0.24^{c}	0.49±0.27^{b}	0.42±0.27^{a}	0.54±0.27
	O (% DM)	41.85±3.24^{d}	35.57±6.39^{a}	40.18±6.64^{bc}	39.59±4.11^{b}	41.13±2.91^{cd}	39.09±6.16
Minerals	P (g/kg DM)	0.62±0.35^{a}	1.13±0.52^{c}	1.05±0.49^{c}	0.77±0.40^{b}	1.23±0.59^{d}	0.96±0.52
	K (g/kg DM)	18.13±7.8^{c}	18.61±7.29^{c}	14.46±8.13^{b}	15.43±7.57^{b}	11.25±5.46^{a}	16.49±7.95
Heating Value	HHV (MJ/kg)	16.05±1.04^{c}	15.39±0.82^{a}	16.32±1.07^{d}	15.77±1.24^{b}	17.36±0.70^{e}	15.96±1.10
	LHV (MJ/kg)	14.62±1.17^{c}	14.08±0.85^{a}	14.98±1.13^{d}	14.32±1.17^{b}	15.69±1.25^{e}	14.60±1.16
Physical & thermal	SHC MJ/(m^3·K)	0.59±0.49^{ab}	0.66±0.48^{b}	0.53±0.50^{a}	0.56±0.50^{a}	0.89±0.30^{c}	0.60±0.49
	TC W/(m·K)	0.10±0.04^{c}	0.08±0.03^{a}	0.10±0.05^{bc}	0.09±0.02^{b}	0.09±0.03^{bc}	0.09±0.04

Note: 1) "±" represents average value and standard deviation;
2) Different superscripted letters in the same row represent a significant difference for different types of manure ($p<0.05$).

Figures 7 – 12 show the boxplots distributions for each characterised property.

3.1.2.1 Chemical composition

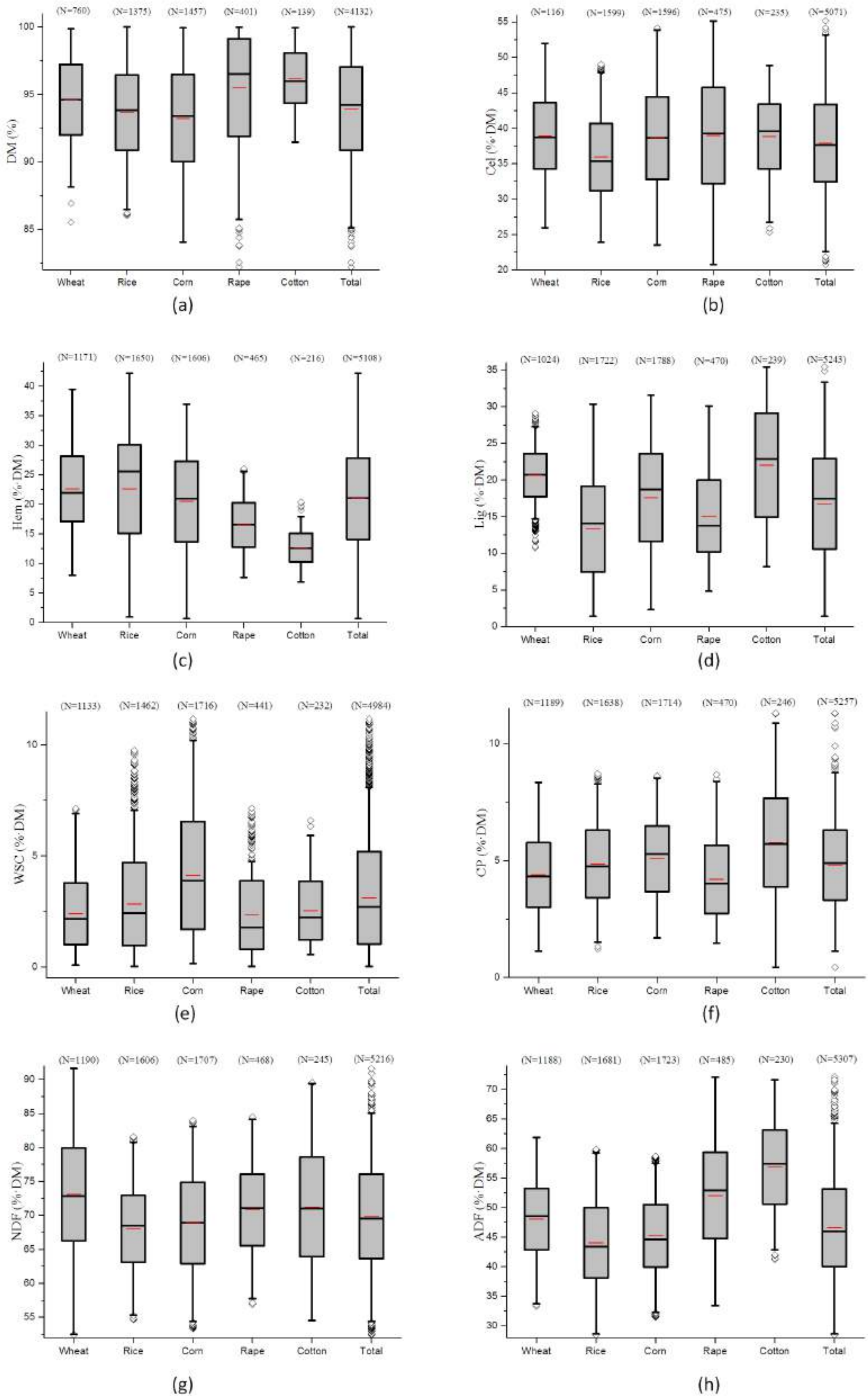


Figure 7: Boxplots distribution of chemical composition of crop residues

3.1.2.2 Proximate analysis

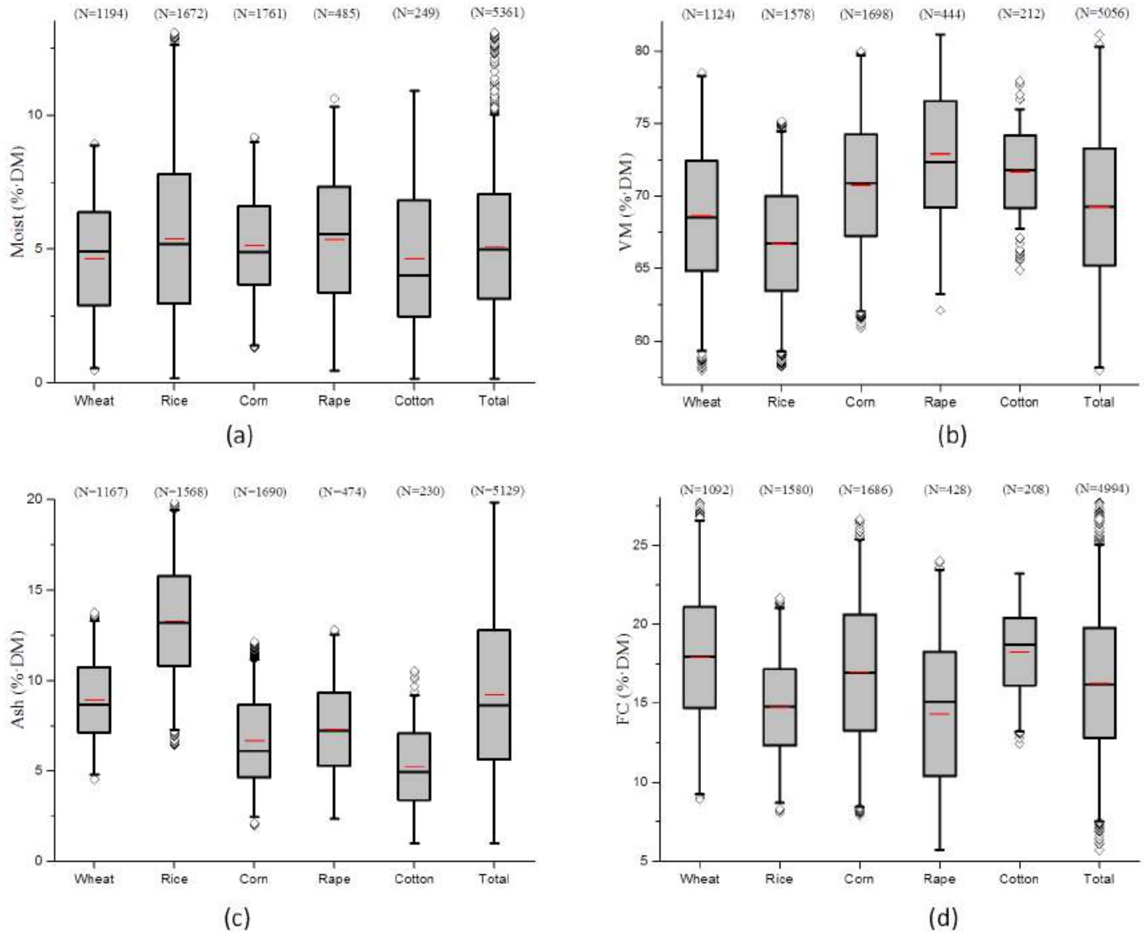


Figure 8: Boxplots distribution of the proximates of crop residues.

3.1.2.3 Ultimate analysis

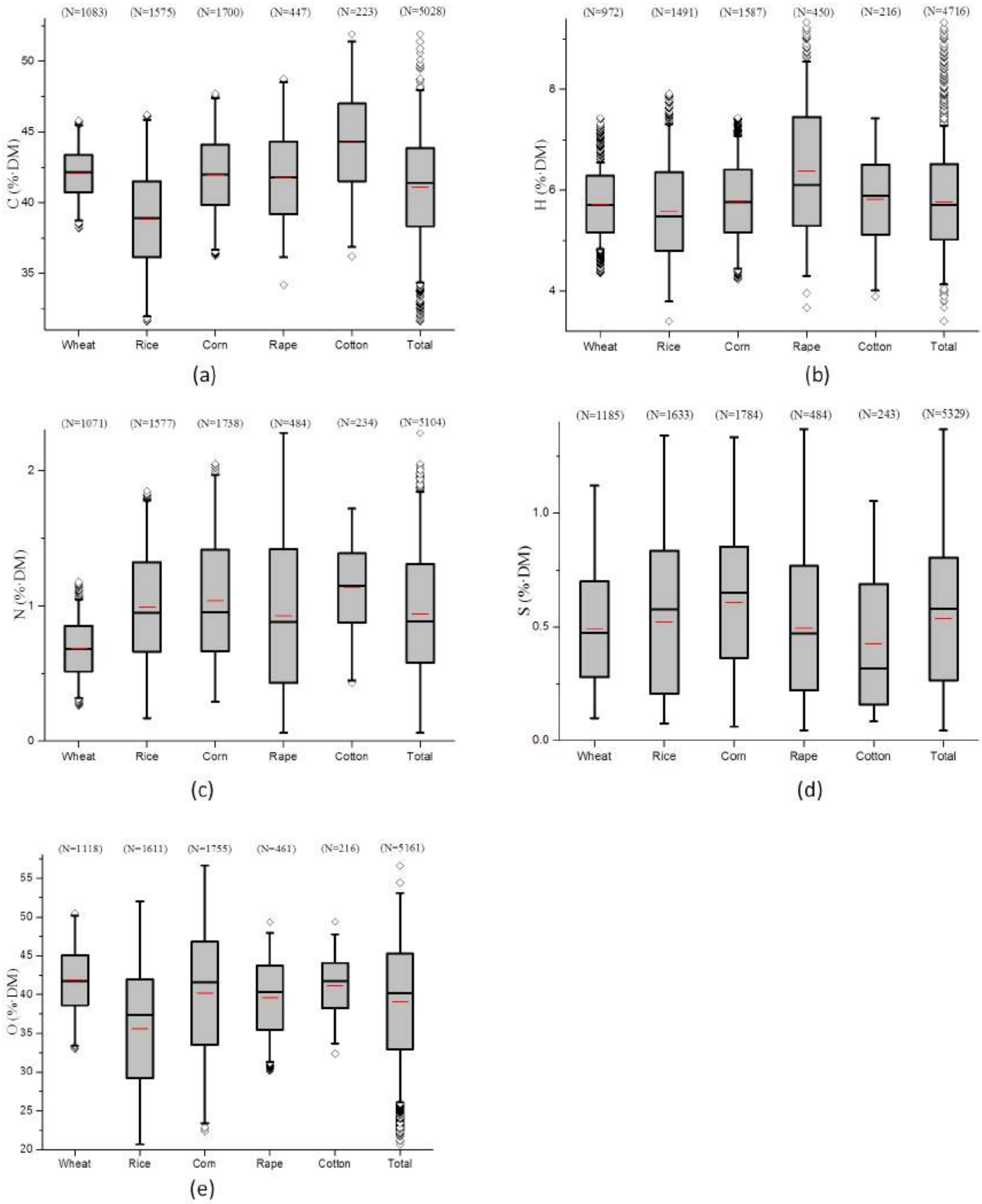


Figure 9: Boxplots distribution of the ultimates of crop residues.

3.1.2.4 Mineral elements

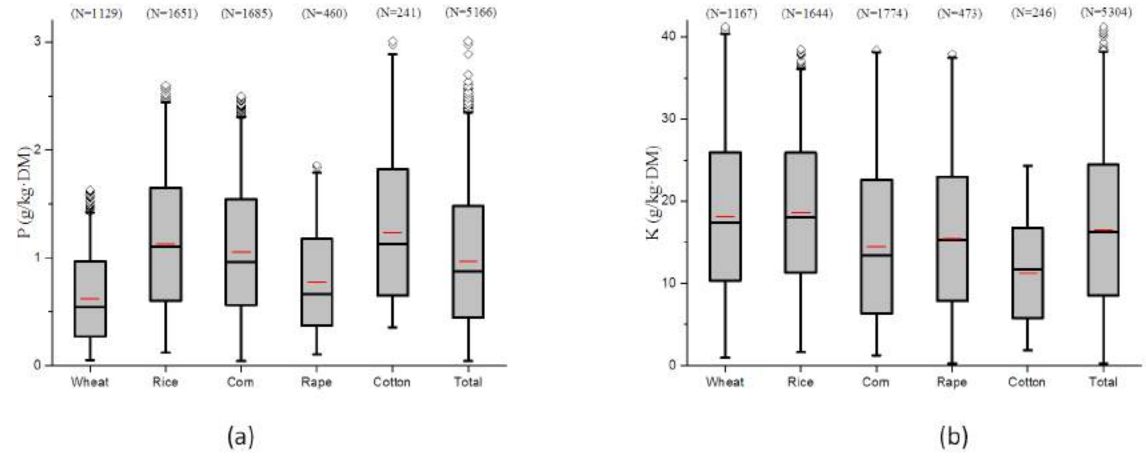


Figure 10: Boxplots distribution of mineral elements of crop residues.

3.1.2.5 Heating values

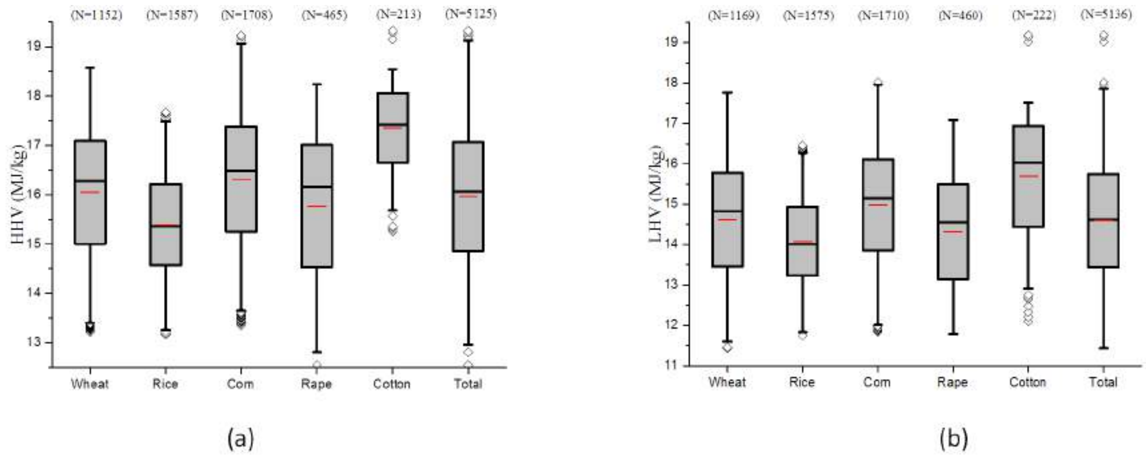


Figure 11: Boxplots distribution of heating values of crop residues.

3.1.2.6 Physical and thermal properties

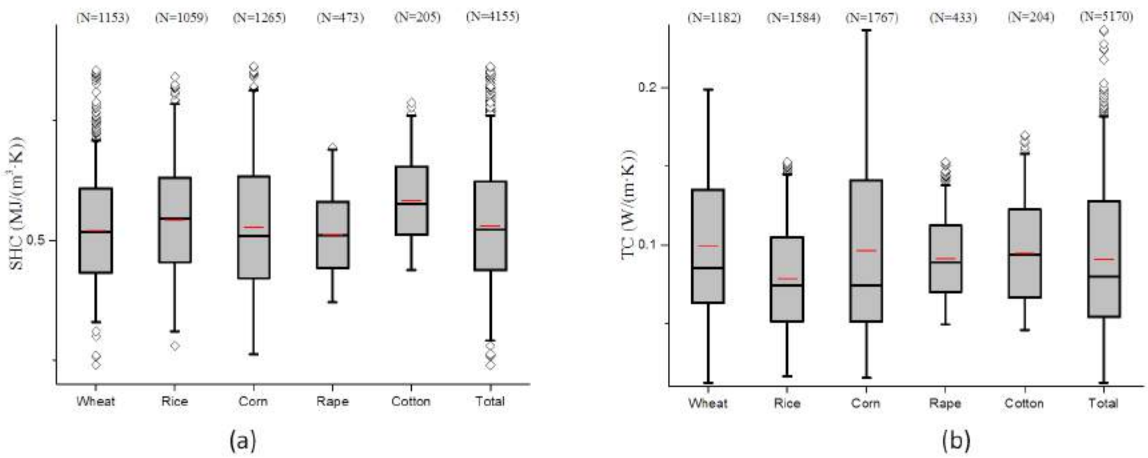


Figure 12: Boxplots distribution of physical and thermal properties of crop residues.

3.2 Characterisation of manure in China

3.2.1 Materials and methods

3.2.1.1 Sample collection and preparation

In this study, 5314 representative samples of livestock and poultry manure were collected from 669 towns in 31 provinces in mainland China, including 878 layer manure samples, 752 broiler manure samples, 956 dairy cattle manure samples, 1007 beef cattle manure samples, and 1721 pig manure samples. The samples were mostly collected from large-scale farms, breeding areas or breeding specialized households. Each sample was collected from different positions on the unit floor in each barn and thoroughly mixed to obtain a representative batch of approximately 2 kg. All the collected samples were dried in a convection oven at 70±5°C for 18 to 24 h until there was no significant loss of moisture according to TMECC 03.09-A. The samples were then ground through a 0.5 mm sieve (Retsch Gmbh, Haan, Germany). The samples were stored in plastic bags before analysis.

3.2.1.2 Sample analysis

The analysis methods for composition, heating values, physical and thermal parameters of manure were listed in Table 5. Composition analysis consists of chemical composition, proximate analysis, ultimate analysis, and mineral elements.

Table 5: Analysis methods for manure.

PROPERTIES		ABBREVIATION	SAMPLES	ANALYTICAL METHODS
Chemical Component	Dry Matter	DM	Fresh	TMECC 03.09-A
	Moisture	-	Fresh	TMECC 03.09-A
	Organic Matter	OM	Prepared	TMECC 05.07-A
	Total Nitrogen	TKN	Prepared	Total Nitrogen (Maurice Watson, Ann Wolf and Nancy Wolf)
	Ammonium Nitrogen	AN	Prepared	Ammonium Nitrogen (John Peters, Ann Wolf and Nancy Wolf)
Proximate Analysis	Volatile Matter	VM	Prepared	ASTM E872 -82(2006) Standard Test Method for Volatile Matter in the Analysis of Particulate Wood Fuels
	Fixed Carbon	FC	Prepared	ASTM E870-82 Standard Test Method for Analysis of Wood Fuels
	Ash	-	Prepared	TMECC 05.07-A
Ultimate Analysis	C	-	Prepared	ASTM E777 -08 Standard Test Method for Carbon and Hydrogen in the Analysis Sample of Refuse-Derived Fuel
	H	-	Prepared	ASTM E777 -08 Standard Test Method for Carbon and Hydrogen in the Analysis Sample of Refuse-Derived Fuel
	N	-	Prepared	AOAC Official Method 993.13 Nitrogen (Total) in Fertilizers
	S	-	Prepared	ISO351:1996,Solid mineral fuels-Determination of total sulfur—High temperature combustion method
	O	-	Prepared	ASTM E870-82(2006) Standard Test Methods for Analysis of Wood Fuels
Mineral Elemental	Total Phosphorus	TP	Prepared	Inductively coupled plasma - mass spectrometry with advanced microwave digestion instrument by HNO_3
	Water-Soluble Phosphorus	AP	Prepared	TMECC 04.03 Method 04.03-B Water-Soluble Phosphorus
	Potassium	K	Prepared	Inductively coupled plasma - mass spectrometry with advanced microwave digestion instrument by HNO_3
Heating Value	Higher Heating Value	HHV	Prepared	ASTM E711–87 Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter
	Lower Heating Value	LHV	Prepared	ASTM E711–87 Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Bomb Calorimeter
Physical & Thermal Analysis	Electrical Conductivity	EC	Fresh	TMECC 04.10-A
	pH	-	Fresh	TMECC 04.11-A
	Specific Heat Capacity	SHC	Prepared	ASTM E1269-05 Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
	Thermal Conductivity	TC	Prepared	GB T 10297-1998 Plan Name in English Test method for thermal conductivity of nonmetal solid materials by hot-wire method

3.2.1.3 Data processing and analysis

Same as described in 3.1.

3.2.2 Results

Table 6 shows the data of different properties for livestock and poultry manure. The contents of chemical components, proximate analysis, ultimate analysis, minerals, and heat value as well as physical & thermal analysis were significantly different for the five types of manure.

Table 6: Compositional and property analysis statistical results of manure.

PROPERTIES		LAYER	BROILER	DAIRY CATTLE	BEEF CATTLE	PIG	TOTAL
Chemical	DM (%)	49.59±28.24^{d}	53.77±27.11^{e}	35.55±22.18^{b}	40.64±25.06^{c}	29.76±7.46^{a}	40.06±23.71
	Moisture (%)	50.26±28.37^{b}	42.57±28.28^{a}	64.74±21.89^{d}	58.04±26.02^{c}	68.25±11.41^{e}	58.53±24.66
	OM (%·DM)	67.27±10.97^{a}	71.90±11.86^{b}	71.95±15.13^{b}	74.29±13.61^{c}	74.78±9.87^{c}	72.51±12.46
	TKN (g/kg·DM)	33.61±23.37^{c}	29.52±23.78^{b}	24.73±19.13^{a}	28.07±24.31^{b}	24.36±17.25^{a}	27.46±21.43
	AN (g/kg·DM)	10.57±9.33^{c}	6.31±6.11^{b}	5.60±4.87^{ab}	4.73±4.34^{a}	6.09±4.49^{b}	6.57±6.18
Proximate	VM (%·DM)	59.13±8.09^{a}	61.59±8.97^{b}	61.55±9.22^{b}	63.39±7.90^{c}	62.28±7.27^{bc}	61.75±8.24
	FC (%·DM)	9.46±5.98^{a}	11.21±4.38^{c}	12.95±4.41^{d}	13.22±4.30^{d}	10.50±3.79^{b}	11.34±4.70
	Ash (%·DM)	28.66±7.54^{d}	23.41±8.23^{c}	20.48±7.49^{b}	19.01±5.73^{a}	22.51±6.14^{c}	22.55±7.52
Ultimate	C (%·DM)	32.32±3.42^{a}	34.09±4.64^{b}	36.31±4.66^{c}	36.61±4.79^{c}	36.30±4.80^{c}	35.47±4.82
	H (%·DM)	5.04±0.99^{a}	5.25±0.95^{b}	5.25±0.84^{b}	5.28±0.80^{b}	5.85±1.09^{c}	5.41±1.01
	N (%·DM)	2.75±0.86^{b}	3.16±1.22^{c}	2.08±0.46^{a}	2.17±0.49^{a}	2.69±0.75^{b}	2.63±1.00
	S (%·DM)	0.67±0.19^{b}	0.74±0.21^{d}	0.64±0.19^{a}	0.66±0.16^{ab}	0.71±0.22^{c}	0.68±0.20
	O (%·DM)	29.28±7.75^{a}	31.03±7.35^{b}	32.18±6.73^{c}	32.53±6.35^{c}	29.79±5.75^{a}	30.87±6.76
Mineral	TP (g/kg·DM)	12.77±4.79^{b}	12.49±5.68^{b}	6.83±3.21^{a}	7.45±4.10^{a}	16.64±7.14^{c}	11.99±6.78
	AP (g/kg·DM)	2.11±1.12^{b}	2.28±1.20^{b}	1.14±0.94^{a}	1.19±0.97^{a}	2.70±1.47^{c}	2.01±1.37
	K (g/kg·DM)	19.71±7.99^{c}	18.40±8.09^{b}	12.86±7.92^{a}	13.23±7.78^{a}	13.14±5.85^{a}	14.98±7.86
Heating value	HHV (MJ/kg·DM)	12.44±2.19^{a}	13.90±2.13^{b}	14.93±2.05^{c}	15.42±1.86^{d}	15.41±2.07^{d}	14.62±2.33
	LHV (MJ/kg·DM)	11.46±2.11^{a}	12.96±2.27^{b}	13.70±2.12^{c}	14.21±1.98^{d}	14.10±2.21^{d}	13.46±2.35
Physical and Thermal	EC (μs/cm)	7440±6246^{d}	5873±3679^{c}	4112±2585^{b}	3051±2078^{a}	3753±2626^{b}	4580±3844
	pH	7.35±0.94^{b}	7.17±1.19^{a}	7.48±1.05^{bc}	7.52±0.95^{c}	7.16±1.02^{a}	7.32±1.04
	SHC (MJ/(m^3·K))	0.860±0.181^{c}	0.886±0.181^{c}	0.686±0.132^{a}	0.677±0.149^{a}	0.820±0.178^{b}	0.785±0.185
	TC (W/(m·K))	0.099±0.020^{c}	0.095±0.022^{b}	0.098±0.027^{bc}	0.086±0.024^{a}	0.096±0.016^{b}	0.095±0.022

Note: 1) "±" represents average value and standard deviation;
2) Different superscripted letters in the same row represent a significant difference for different types of manure ($p<0.05$).

Figures 13 – 18 show the boxplots distributions for each characterised property.

3.2.2.1 Chemical composition

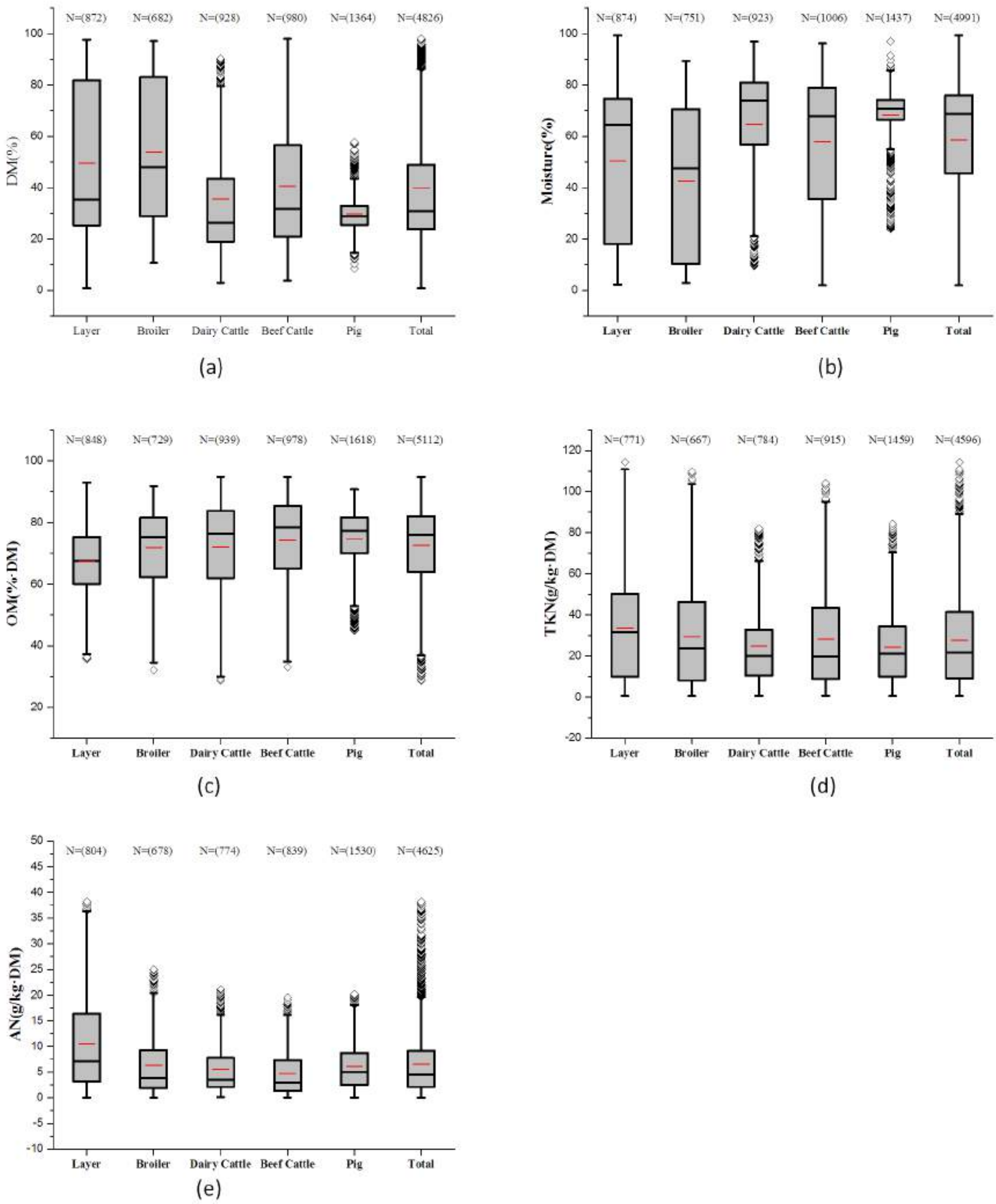


Figure 13: Boxplots distribution of chemical composition of manure.

3.2.2.2 Proximate analysis

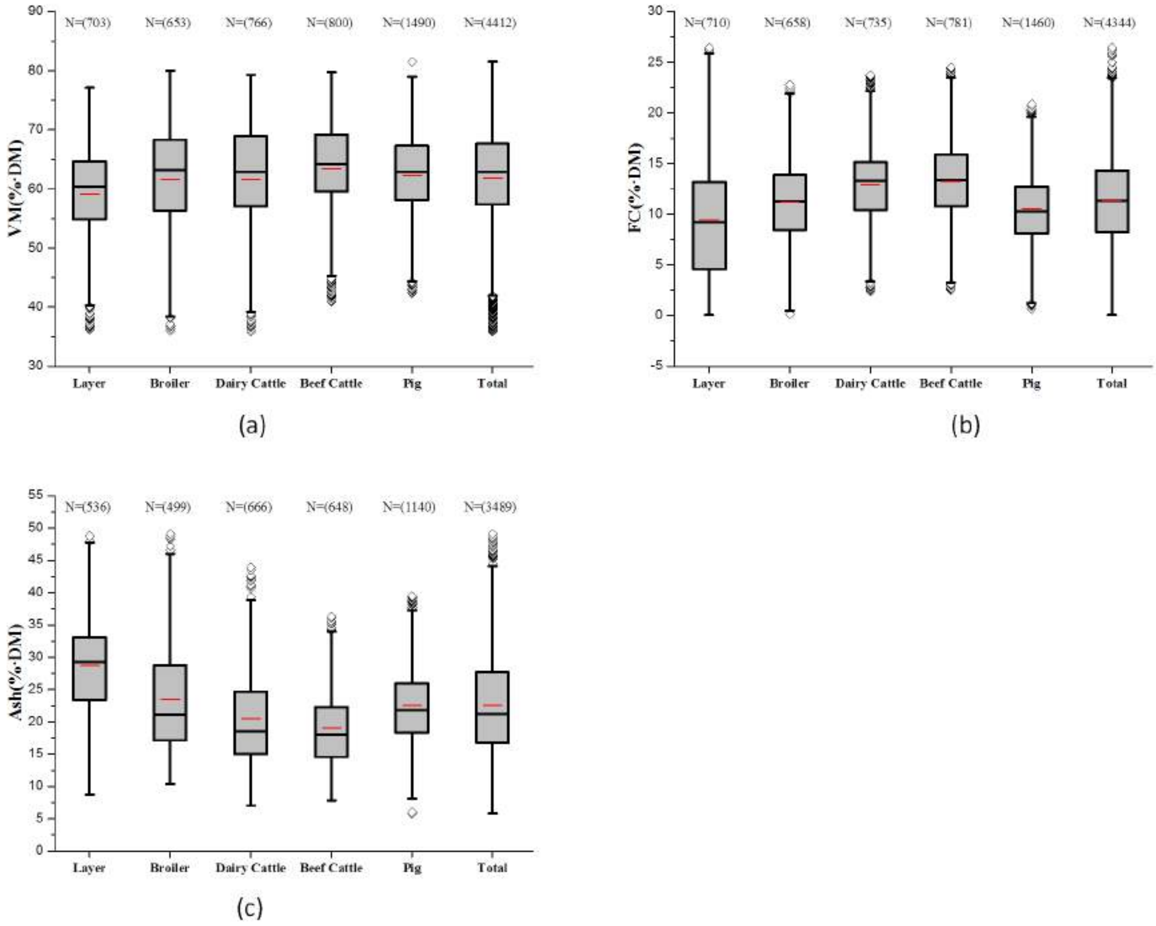


Figure 14: Boxplots distribution of the proximates of manure.

3.2.2.3 Ultimate analysis

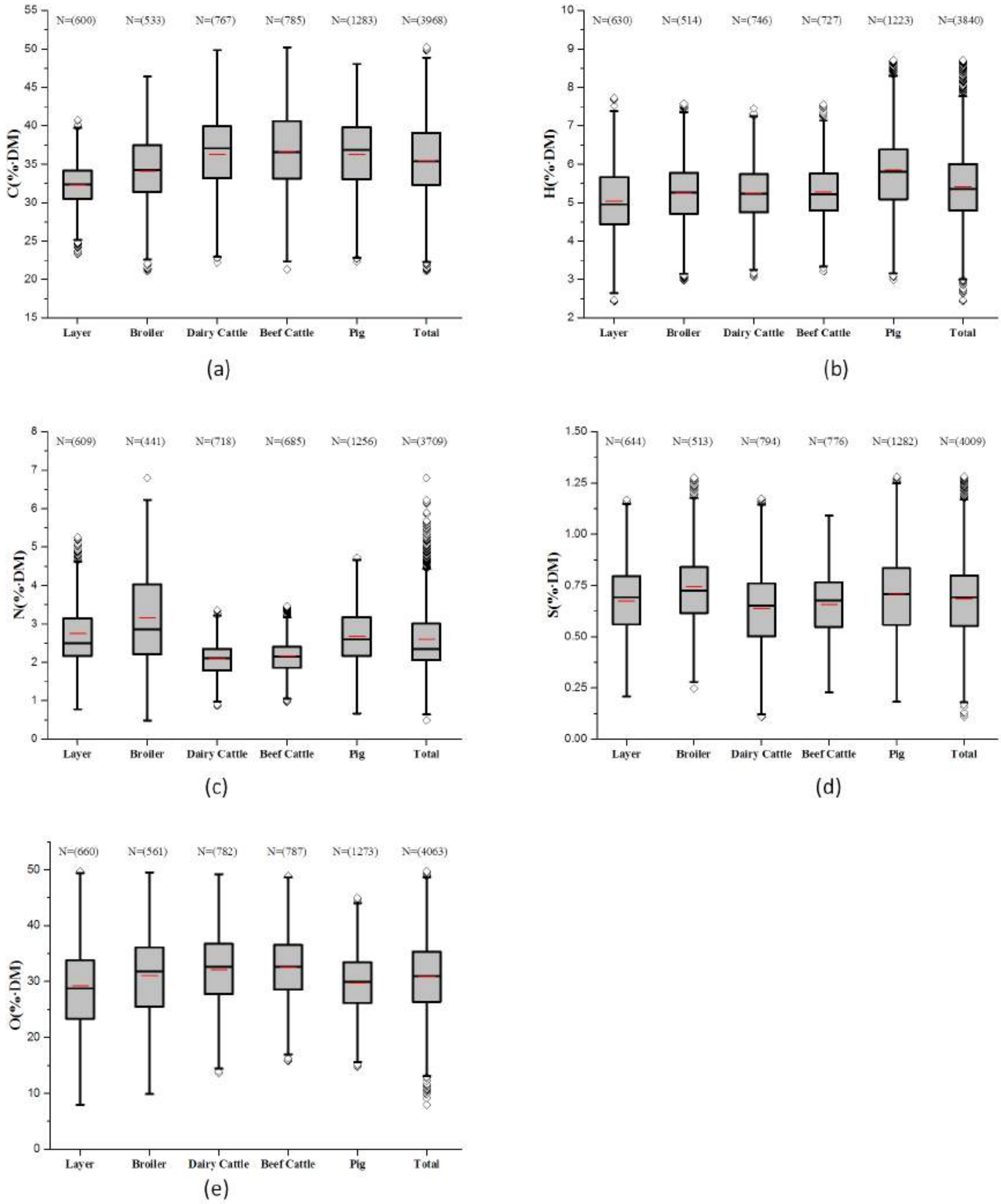


Figure 15: Boxplots distribution of the ultimates of manure.

3.2.2.4 Mineral elements

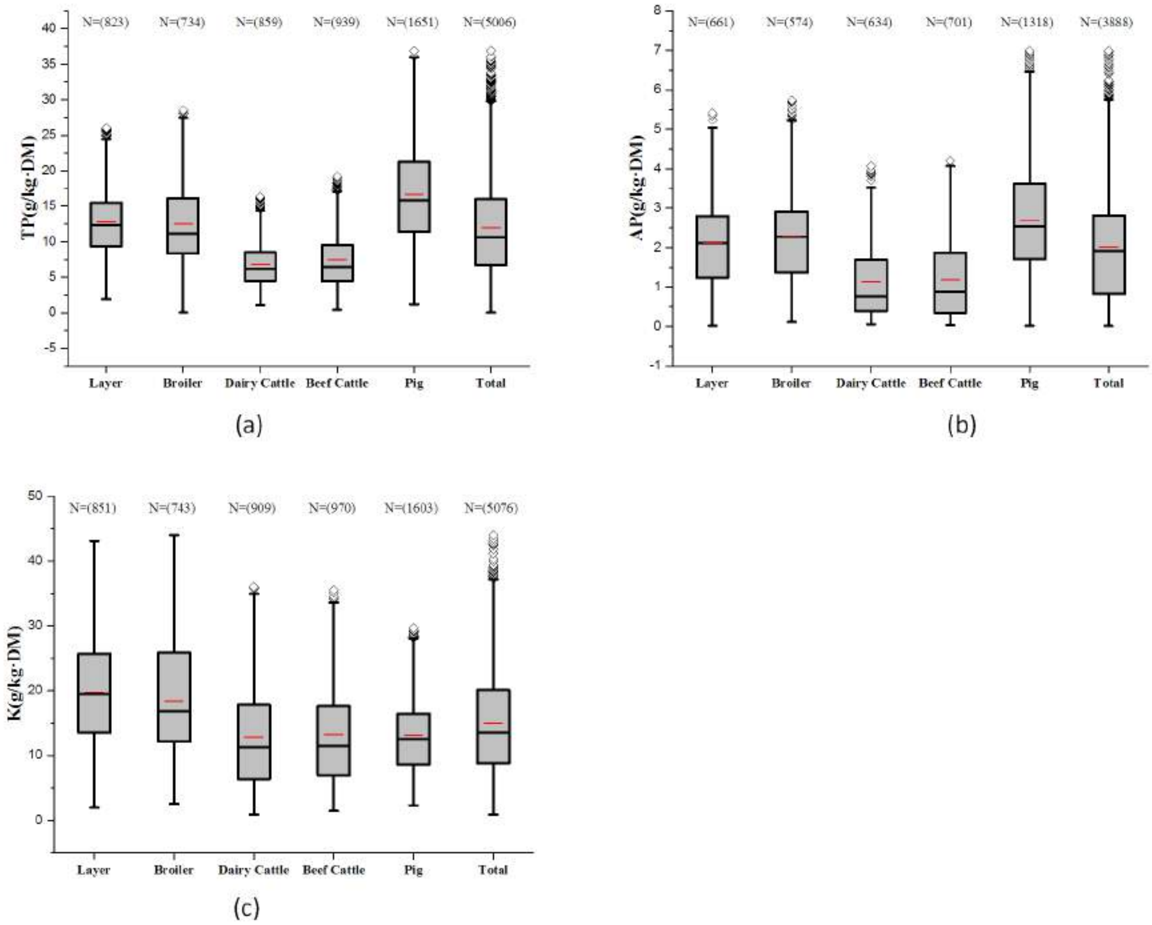


Figure 16: Boxplots distribution of mineral elements of manure.

3.2.2.5 Heating values

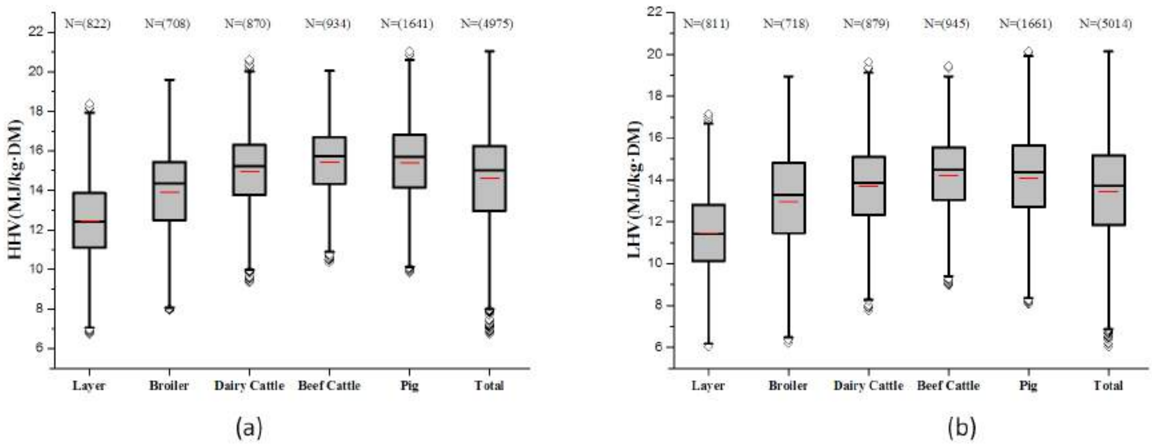


Figure 17: Boxplots distribution of heating values of manure.

3.2.2.6 Physical and thermal properties

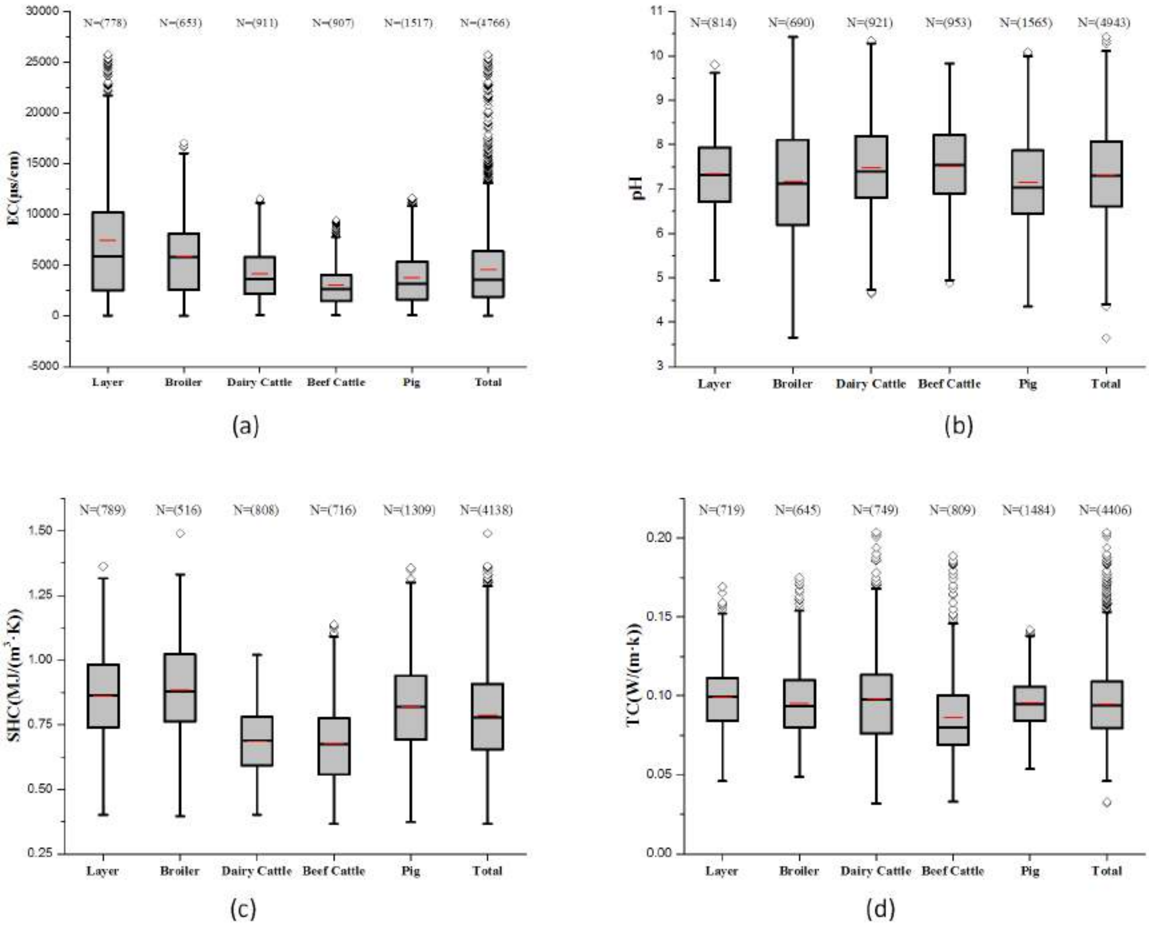


Figure 18: Boxplots distribution of physical and thermal properties of manure.

4. Summarizing policy supporting documents and existing techniques on AWCB processing and utilisation in China

4.1 Policy and regulation for crop residue utilisation

To utilise crop residue resources more effectively and to enhance the development of recyclable agriculture, the central government of China has published a series of policies and regulations, including:

1) Legislated new laws and regulations to control crop residue burning. For instance, the government enforced Law of Prevention of Air Pollution in 2003, Management of Regulations on Straw Banning and Comprehensive Utilizations, and Notice on Strengthening the Work of Straw Banning and Comprehensive Utilization in 2014 (Chen et al., 2016);
2) Set up pilot projects to promote new technologies for crop residue processing and unitization. During the 12th Five-Year Plan, the government set up various key projects, including crop residue recycling agriculture demonstration project to achieve 10% crop residue utilisation in specific regions by 2015; crop residue for industrial material project to reach 1.5-2.0×10^8 t of annual crop residue utilisation for paper and wood-plastic composites production; and power plant demonstration project to achieve 30% crop residue utilisation for power generation by 2015.
3) Adopted tax supports. The government has published tax support policies on crop residue power generation project since 2005. Also, tax support policies were made to improve soil organic matter in both 2009 and 2010;
4) Promoted production-teaching-research project for new technology development. The newly released "Plan to Promote the Utilization of Agricultural Wastes" (2016) has emphasized to encourage biofuel research and to implement bio-based materials technology demonstration projects.

4.2 Policy and regulation for manure utilisation

As China's livestock industry continues to grow and modernize quickly, manure management is becoming a critical obstacle to growth (U.S. Grains Council). To deal with the ecological problems, series of policies such as regulation, subsidy, pollution charges and rewards have been launched by the Chinese government to ensure the production of livestock can be sustainable (Pan, 2016).

"Regulation on the Prevention and Control of Pollution from Large-scale Breeding of Livestock and Poultry" was established in 2013 to diminish the impact of manure emissions on ecosystem. In addition, the eco-friendly utilisation of manure as fertilizer and biogas production has been encouraged according to the regulation.

A series of biogas subsidy programs have been introduced to rural areas by the Chinese government since 2002. According to the "Agricultural biomass energy industry development plan (2007-2015)" the household biogas digesters in China expanded to around 60 million and the total number of large and medium-sized biogas projects in large-scale farms in China reached 8,000 by the end of 2015.

"Plan to Promote the Utilization of Agricultural Wastes" released on 11 August, 2016 schedules to carry out pilot demonstration projects for agricultural waste utilisation in about 30 counties (cities) of China.

Note

To ensure the scientific and representative of our large number of data, further data processing and literature investigation is still undergoing.

5. Reference list

Chaoling Chen, Yang Yang, Guanghui Xie. Study of the Development of Crop Straw Management Policy in China.. Journal of China Agricultural University. 2016, 21(8): 1-11. (in Chinese)

China Statistical Yearbook. 2015. (in Chinese)

Chou Huanguang, Mo Haixia, Bai Junfei, Cai Yaqing, Wang Jinxia. Manure Treatment Methods and Influencing Factors of Livestock and Poultry in China - An Empirical Analysis Based on Five Provinces Survey Data. China Rural Economy [J]. 2012, 3:78-87. (in Chinese)

Jia W., Yan Z., Chadwick D.R., Kang L., Duan Z., Bai Z., Chen Q. Integrating soil testing phosphorus into environmentally based manure management in peri-urban regions: A case study in the Beijing area. Agric. Ecosyst. Environ. 2015, 209, 47–49.

Lin, Y., Ma, j., Qin, F., The Structure Distribution and Prospect of China Manure Resource, *Chinese Agricultural Science Bulletin (in Chinese)*, 28 (32), 2012, 1-5.

Pan, D., The Design of Policy Instruments towards. Sustainable Livestock Production in China: An Application of the Choice Experiment Method, *Sustainability*, 8 (7), 2016, 3-18.

Shan, H., Wu, Y., Xu, Y., He, Z., Current situation and existing problems of livestock manure reutilization, *China Poultry (in Chinese)*, 29 (16), 2007, 44-45.

Yuyun Bi. Study on Straw Resources Evaluation and Utilization in China. 2010. PhD Dissertation. Chinese Academy of Agricultural Sciences. (in Chinese)

Zhu, F., Ma, Y., Zhou, J., Guan, J., Liang, J., Zhao, Y., Analysis on Present situation of Pollution and utilization of Animal excrement in China, *Anhui Agricultural Science Bulletin (in Chinese)*, 14 (13), 2008.

Zhu, N., Ma, J., Changes and Outlook about Production Amount of Livestock and Poultry Manure in China, *Agricultural Outlook (in Chinese)*, 1, 2014, 46-48.