The use of oral fluid diagnostics in swine medicine

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Summary

Swine veterinarians in North America have applied oral fluid-based testing methodologies for an increasing number of systemic, respiratory, and enteric disease diagnostic applications. Since the first report of oral fluid testing in 2008, nucleic acid and antibody assays have been described in the peer-reviewed literature for many pathogens affecting swine. As evidence of the US swine industry's growing utility of oral fluids as a diagnostic tool, the cumulative number of swine oral fluid diagnostic tests conducted at three veterinary diagnostic laboratories in the upper Midwest (Iowa State University, South Dakota State University, and University of Minnesota) has increased from approximately 21,000 tests in 2010 to nearly 370,000 tests in 2016. The objective of this review is to describe the developments in oral fluid diagnostics that have led to its widespread use and to highlight areas of concern as this technology is increasingly implemented by producers and veterinarians.

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Resumen – El uso de diagnósticos con fluido oral en medicina porcina

En Norteamérica, los veterinarios especialistas en cerdos han utilizado metodologías de testeo basadas en fluidos orales para diferentes aplicaciones diagnósticas en un creciente número de enfermedades sistémicas, respiratorias y entéricas. Desde el primer reporte de testeo con fluido oral en 2008, en la literatura editada, se han descrito diferentes ensayos para ácido nucleico y anticuerpos, para muchos patógenos que afectan a los cerdos. Como evidencia del creciente uso en la industria porcina de los Estados Unidos de los fluidos orales como herramienta de diagnóstico, el número acumulado de pruebas de diagnóstico de fluido oral porcino conducidas en tres laboratorios de diagnóstico veterinario en la parte superior del Medio Oeste (Universidad del Estado de Iowa, Universidad del Estado de Dakota del Sur, y Universidad de Minnesota) se han incrementado de aproximadamente 21,000 pruebas en 2010 a cerca de 370,000 pruebas en 2016. El objetivo de esta revisión es describir los desarrollos en el diagnóstico de fluido oral que han llevado a su uso generalizado y resaltar las áreas de preocupación conforme esta tecnología es implementada, cada vez más, por productores y veterinarios.

Résumé – Utilisation des fluides oraux aux fins de diagnostics en médecine porcine

En Amérique du Nord les vétérinaires en médecine porcine ont appliqué des méthodologies utilisant les fluides oraux dans un nombre croissant d'applications diagnostiques pour des maladies systémiques, respiratoires et entériques. Depuis le premier rapport en 2008 de test utilisant du fluide oral, des épreuves pour détecter des acides nucléiques et des anticorps ont été décrites dans la littérature jugées par les pairs pour plusieurs agents pathogènes affectant les porcs. À titre de preuve de l'utilité grandissante dans l'industrie porcine américaine des fluides oraux comme outil diagnostique, le nombre cumulatif d'épreuves diagnostiques effectuées sur du fluide oral dans trois laboratoires de diagnostic vétérinaires dans le Midwest (Iowa State University, South Dakota State University, and University of Minnesota) a augmenté d'environ 21,000 test en 2010 à environ 370,000 tests en 2016. L'objectif de la présente revue est de décrire les développements dans le diagnostic utilisant les fluides oraux qui ont mené à cet usage répandu et de faire ressortir les inquiétudes étant donné que l'application de cette technologie est en augmentation par les producteurs et les vétérinaires.

The first technical report on swine oral fluid diagnostics was presented at the 2005 International PRRS Symposium when Simer et al[1] reported 20 of 24 pen-based oral fluid samples (83.3%) and 17 of 24 serum samples (70.8%) were porcine reproductive and respiratory syndrome virus (PRRSV) reverse transcription polymerase chain reaction (RT-PCR) positive in finishing pigs. The purpose of this review is to provide an update on the development and implementation of oral fluid diagnostics in swine medicine subsequent to this initial report.

Collection of oral fluid samples has been described at length by Prickett et al.[2] In brief, cotton ropes are hung in the pen at pig shoulder height. Pigs chew on the rope, saturating the rope with oral fluids. After 20 to 30 minutes, the ropes are placed in a single-use plastic bag, the fluid is wrung from the rope, and

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then decanted into a tube for submission to the diagnostic laboratory. Pigs with prior experience respond immediately to the presence of the rope. In experienced groups, a 20- to 30-minute sampling period is sufficient to allow adequate participation of pigs in the pen. In pigs without prior rope sampling experience, 60 minutes is recommended to allow pigs to learn the new "game" and achieve an adequate level of participation.[3]

Oral fluids are most commonly collected from pens of pigs, but oral fluid samples can also be obtained from individual pigs.[3] Oral fluids can be successfully collected at all production stages, ie, growing pigs[3,4] and in the breeding herd for individually- or group-housed sows and boars.[5,6] Samples can be collected from suckling piglets as they approach weaning age,[7,8] but family sampling, ie, placing the rope so that both sows and their litters have access, has been shown to be more successful than collecting solely from the piglets. Thus, Almeida et al[8] reported an approximate 73% success rate when collecting family oral fluid samples versus 44% success when collecting only from litters. From a collection of 72 family oral fluid samples and matching sera from 718 piglets, 84.4% (27 of 32 litters) were PRRSV RT-PCR positive while 24.2% (174 of 718 piglets) of serum samples were positive for PRRSV nucleic acid.

At the present time, the detection of nucleic acid or antibodies in oral fluids has been documented for most of the major swine pathogens including: *Actinobacillus pleuropneumoniae* (APP),[9,10] African swine fever virus,[11,12] classical swine fever virus,[13] foot-and-mouth disease virus,[14,15] influenza A virus (IAV),[16-18] *Lawsonia intracellularis*,[19] *Mycoplasma* spp.,[20-22] porcine circovirus type 2 (PCV2),[2,23] porcine epidemic diarrhea virus (PEDV),[24] PRRSV,[2,6,25-27] Senecavirus A (SVA),[28] and others. Field applications or research on the use of oral fluid diagnostics have been described in Australia,[15] Belgium,[29] Canada,[30] France,[31] Germany,[13] Italy,[32] Japan,[33] Malaysia,[34] Poland,[35] Spain,[36] the United Kingdom,[37,38] the United States,[2] Vietnam,[39] and others. Many of the assays reported in the literature have only been described under research conditions, but it is reasonable to expect their future commercialization and adoption for routine use in diagnostic laboratories.

Oral fluid testing

In the United States, veterinary diagnostic laboratories with a major swine focus began offering oral fluid-based tests to clientele in 2010. The data provided in Figure 1 and Tables 1, 2, 3, and 4 describe the number of oral fluid tests performed at Iowa State University, South Dakota State University, and University of Minnesota. The following is a review of pathogens for which testing is commonly performed and for which peer-reviewed literature is available.

Porcine reproductive and respiratory syndrome virus

Porcine reproductive and respiratory syndrome virus was the first virus detected by RT-PCR in oral fluid samples.[2] Porcine reproductive and respiratory syndrome virus oral fluid enzyme-linked immunosorbent assays (ELISA) for antibody detection have been routinely offered since 2010. In 2016, RNA detection was performed for 116,671 of the 148,526 PRRSV tests (Tables 1 and 2).

Nucleic acid detection

Prickett et al[2] first reported the detection of PRRSV by quantitative RT-PCR (qRT-PCR) in oral fluids collected in the field from 8-week-old pigs. Oral fluid qRT-PCR-positive results were coincident with RT-PCR-positive serum samples, ie, showed 77% agreement. Under experimental conditions, Prickett et al[25] reported that PRRSV RNA was detected in oral fluid samples from 3 to 35 days post inoculation (DPI), with sporadic positives thereafter. Similar results were obtained from individual boars inoculated with modified-live virus, type 1 PRRSV, or type 2 PRRSV.[6] On the first DPI, virus was detected in 10% of the boars sampled (7 of 69); by 3 DPI, virus was detected in 100% of boars sampled (67 of 67).[6] Cumulatively, the literature indicates that PRRSV RNA can be detected for at least 36 DPI in oral fluid samples.[5,25,26,33,35,40-44]

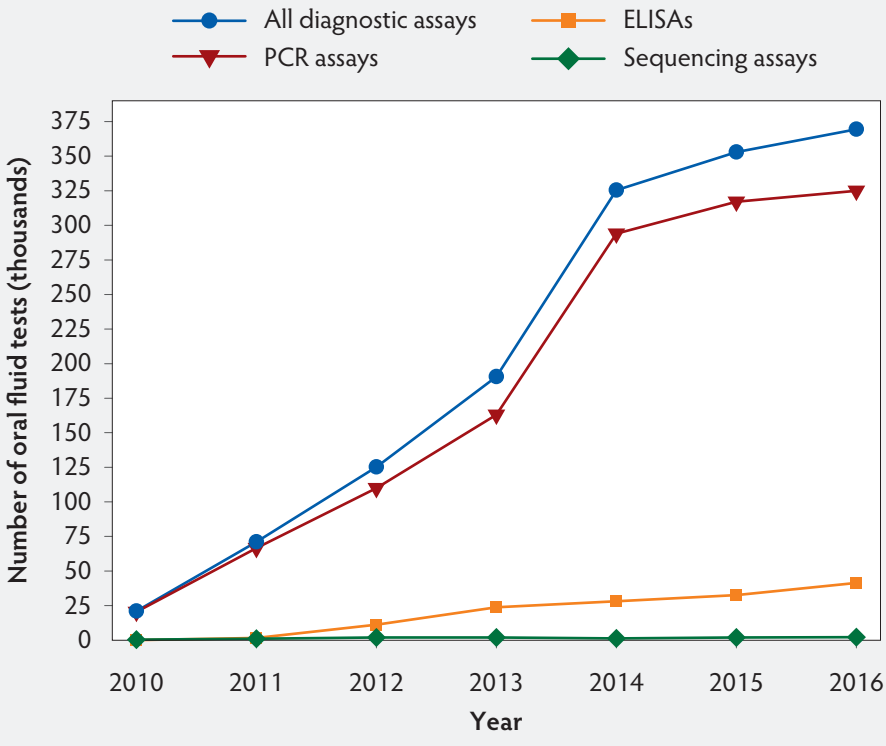
Sequencing

Successful PRRSV sequencing from oral fluids has been described.[35,45,46] Kittawornrat et al[45] obtained PRRSV open reading frame-5 sequences from 2 of 6 RT-PCR-positive oral fluid samples from pre-weaned pigs. Zhang et al[46] reported successful full-genome sequencing from oral fluid samples with RT-PCR cycle threshold (Ct) values between 18.7 and 20.6, whereas no full-length sequences were obtained from oral fluids with Ct values between 22.9 and 35.4.

Antibody detection

Porcine reproductive and respiratory syndrome virus IgG antibody is detected in

Figure 1: Total number of oral fluid tests conducted at Iowa State University, South Dakota State University, and the University of Minnesota from 2010 to 2016. PCR = polymerase chain reaction; ELISA = enzyme-linked immunosorbant assay.



oral fluids by ELISA between 7 and 14 days after inoculation or vaccination.[5,25-27,40,47] Kittawornrat et al,[27] working with oral fluid samples from individually housed boars and a serum ELISA adapted to oral fluids, reported that IgM was detectable at 3 DPI, IgA at 7 DPI, and IgG at 8 DPI. Antibody responses in oral fluids mirrored antibody responses in serum. Maternal PRRSV IgG is readily detected in pigs from PRRSV-positive sow herds and may be detected for up to 60 days post-weaning; however, a PRRSV IgM-IgA (dual isotype) ELISA was shown to detect pig-specific IgM and IgA, even in the presence of maternal IgG.[48] Porcine reproductive and respiratory syndrome virus antibody ELISA testing has been well documented in the literature and may provide a cost-effective approach to PRRSV monitoring and surveillance.

Influenza A virus

As shown in Tables 1, 2, 3, and 4, IAV oral fluid testing has been offered for routine testing since 2010. Nucleic acid detection was performed for 42,261 of the 47,454 IAV tests in 2016 (Table 1 and 2).

Table 1: Total number of tests on oral fluid specimens by pathogen in 3 US veterinary diagnostic laboratories from 2010 to 2016 *

Pathogen	2010	2011	2012	2013	2014	2015	2016
PRRSV	14,603	46,239	77,756	109,868	126,165	144,773	148,526
IAV	4785	16,495	34,297	46,940	48,688	48,895	47,454
MHP	760	4514	7079	10,286	11,203	11,741	13,178
PCV2	751	2047	4147	2149	5676	4807	3176
APP	0	37	4	93	14	287	3306
TGEV	0	34	0	4651	32,848	12,497	12,996
PEDV	0	0	0	14,361	75,965	76,063	73,494
LI	0	0	0	454	1519	3290	2443
PDCoV	0	0	0	0	21,393	46,366	58,513
SVA	0	0	0	0	0	1597	3598
Other	64	1630	1919	1804	2010	2595	2755
Total	20,963	70,996	125,202	190,606	325,481	352,911	369,439

* Iowa State University, South Dakota State University, and University of Minnesota.
PRRSV = porcine reproductive and respiratory syndrome virus; IAV = influenza A virus; MHP = *Mycoplasma hyopneumoniae*; PCV2 = porcine circovirus type 2; APP = *Actinobacillus pleuropneumoniae*; TGEV = transmissible gastroenteritis virus; PEDV = porcine epidemic diarrhea virus; LI = *Lawsonia intracellularis*; PDCoV = porcine deltacoronavirus; SVA = Senecavirus A.

Table 2: Number of nucleic acid (PCR) tests on oral fluid specimens in 3 US veterinary diagnostic laboratories from 2010 to 2016*

Pathogen	2010	2011	2012	2013	2014	2015	2016
PRRSV	14,251	43,464	64,984	84,835	96,715	110,650	116,671
IAV	4581	14,898	31,806	44,410	46,738	47,304	42,261
PCV2	751	2047	4147	2142	5669	4773	3168
MHP	750	4514	7056	10,271	11,201	11,708	13,169
TGEV	0	34	0	4651	32,848	12,497	12,996
PEDV	0	0	0	14,361	75,931	76,048	69,324
LI	0	0	0	454	1519	3290	2443
PDCoV	0	0	0	0	21,393	46,365	58,513
SVA	0	0	0	0	0	1597	3533
Other	64	1584	1923	1881	2024	2863	2886
Total	20,397	66,541	109,916	163,005	294,038	317,095	324,964

* Iowa State University, South Dakota State University, and University of Minnesota.
PCR = polymerase chain reaction; PRRSV = porcine reproductive and respiratory syndrome virus; IAV = influenza A virus; MHP = *Mycoplasma hyopneumoniae*; PCV2 = porcine circovirus type 2; TGEV = transmissible gastroenteritis virus; PEDV = porcine epidemic diarrhea virus; LI = *Lawsonia intracellularis*; PDCoV = porcine deltacoronavirus; SVA = Senecavirus A.

Nucleic acid detection

Detmer et al[49] first reported the detection of IAV nucleic acid in oral fluid samples from both experimentally and naturally infected pigs. Under experimental conditions, IAV RNA was detected in oral fluids from 3 to 21 DPI; whereas, no IAV RT-PCR-positive nasal swabs were detected past 7 DPI.[50] Ramirez et al[43] reported highly variable detection patterns for IAV infection in 10 wean-to-finish barns. Cumulatively, the literature indicates that IAV RNA can be detected in oral fluids, but widely variable detection patterns have been noted in the literature.[35,37,50-54]

Sequencing

Influenza A virus sequencing has been described in the literature.[49,51,53] Detmer et al[49] obtained hemagglutinin (HA) sequences from 2 of 4 positive oral fluid samples submitted for analysis. Panyasing et al[53] reported unsuccessful attempts to sequence HA and neuraminidase genes, but successfully sequenced M genes for all 18 IAV qRT-PCR-positive oral fluid samples collected from neonatal pigs. In oral fluid field samples submitted for routine analysis, HA sequences were obtained from 34 of 61 (55.7%) samples with Ct values < 25; 5 of 34 (14.7%) samples with Ct values between 25 and 29.9; and 0 of 39 (0%) samples with Ct values > 30 (Jianqiang Zhang, Personal Communication).

Virus isolation

Isolation of IAV from oral fluids in pigs is difficult and reports of both success and failure may be found in the literature. Detmer et al[49] and Allerson et al[51] were not able to isolate and sequence IAV from oral fluid samples. However, Romagosa et al[54] reported 51.4% (19 of 37) of RT-PCR-positive oral fluid samples were also positive by virus isolation. Similarly, Goodell et al[16] reported successful IAV virus isolation, but isolation was significantly less likely in oral fluids when compared to nasal swabs, particularly in vaccinated animals. Virus isolation was successful in 82 of 180 (45.6%) oral fluid samples with Ct values < 25; 62 of 346 (17.9%) samples with Ct values between 25 and 29.9; and 21 of 407 (5.2%) samples with Ct values between 30 and 35 (Jianqiang Zhang, Personal Communication). Additional research is needed to determine the best time to collect samples and the optimum laboratory protocol for successful IAV virus isolation.[16,49] As reviewed by Baron et al[55] in the context of human immunodeficiency virus, the extreme hypotonicity of oral fluids (one-seventh the tonicity of interstitial fluid) severely reduces virus infectivity. This is a factor that should be considered for future research because, like humans, swine oral fluids are hypotonic and may have an impact on the isolation of IAV and other viral agents from porcine oral fluids.

Antibody detection

Panyasing et al[18] first reported detection of IAV-specific antibodies in oral fluid samples using a blocking ELISA based on the viral nucleoprotein (NP). Using a NP indirect ELISA, IAV IgM antibody responses peaked at 8 DPI and declined quickly thereafter while IgA and IgG were detected around 6 DPI and lasted through the conclusion of the study (42 DPI).[17] In this same study, Panyasing et al[17] showed a rapid anamnestic oral fluid antibody response in vaccinated animals. Cumulatively, the literature agrees that IAV antibodies can be detected in oral fluids as early as 6 DPI.[17,39,52,56,57]

Porcine coronaviruses

The majority of research on the porcine coronaviruses has focused on PEDV. Cumulatively, the research strongly supports the use of oral fluids for PEDV detection. Similar assumptions have been made for other porcine coronaviruses, ie, transmissible gastroenteritis virus and porcine deltacoronavirus (PDCoV), on the strength of the PEDV research.

Porcine epidemic diarrhea virus

Porcine epidemic diarrhea virus RT-PCR testing for oral fluids was implemented in 2013 and was used extensively thereafter, as reflected in the test numbers reported in Tables 1, 2, 3, and 4. Oral fluid antibody testing for PEDV became available in 2016 (Table 3). Reverse transcription PCR testing was performed for 69,324 of the 73,494 PEDV tests conducted in 2016 (Tables 1 and 2).

Nucleic acid detection. Bjustrom-Kraft et al[24] published the first peer-reviewed study on the detection of PEDV in oral fluid samples by RT-PCR. Detectable levels of PEDV were found in fecal swabs, oral fluids, and pen fecal samples collected in the field following a natural planned exposure to PEDV. Significant differences were detected between individual fecal swabs and pen-based oral fluid; oral fluids had lower Ct values indicating higher virus concentrations. PEDV was detected in oral fluids for approximately 69 days post exposure (DPE). Under experimental conditions, Bower et al[58] reported detection of PEDV by RT-PCR in fecal swabs and oral fluids from 1 to 35 DPI in both sample types.

Antibody detection. Bjustrom-Kraft et al[24] reported the detection of PEDV IgG and IgA in oral fluid samples collected 13 days after natural planned exposure. Porcine epidemic diarrhea virus IgA sample to positive ratio (S/P) responses in oral fluid increased until 97 DPE whereas oral fluid IgG responses peaked at 13 DPE and declined thereafter.

Porcine deltacoronavirus

Under experimental conditions, Zhang[59] reported detection of PDCoV in oral fluids from 3-week-old pigs. Individual fecal swabs, pen-based feces, and oral fluids were collected and PDCoV RNA was detected from 7 to 28 DPI, 7 to 14 DPI, and 7 to 35 DPI, respectively. Homwong et al[60] evaluated PDCoV RT-PCR testing results from routine submissions (n = 602) to the University of Minnesota Veterinary Diagnostic Laboratory and found that oral fluid samples were more likely to test positive for PDCoV than feces.

Less commonly used oral fluid tests in the United States

Tests are offered at the diagnostic laboratories for several pathogens for which little peer-reviewed literature is available.

Porcine circovirus type 2

As shown in Tables 1, 2, and 4, routine PCV2 oral fluid testing began in 2010. Relatively few tests have been performed in recent years, which suggests that the current PCV2 vaccines are effective.[61] Porcine circovirus type 2 was detected in oral fluids from each of the three sites with at least 1 to 2 positive samples in oral fluids by quantitative polymerase chain reaction (qPCR) in 2008.[2] Similar results were reported in PCV2-inoculated 11-week-old pigs where PCV2 was detected by qPCR from 2 DPI until the conclusion of the study (98 DPI).[23] Ramirez et al[43] reported 508 of 600 (84.7%) oral fluid samples were PCV2 positive by qPCR in 10 wean-to-finish barns. Van Cuong et al[39] reported a slightly lower PCV2 detection rate (61%) in 68 farms throughout Vietnam. Under experimental conditions, PCV2 antibody (IgG, IgA, and IgM) was first reported in 2011.[23] All PCV2-inoculated pigs seroconverted between 14 and 21 DPI (IgG, IgA, and IgM), and antibody responses remained detectable through the conclusion of the study (98 DPI).

Table 3: Number of antibody (ELISA) tests on oral fluid specimens in 3 US veterinary diagnostic laboratories from 2010 to 2016*

Pathogen	2010	2011	2012	2013	2014	2015	2016
PRRSV	43	1575	11,224	23,785	28,107	32,564	30,051
MHP	10	0	0	4	1	33	8
IAV	0	0	5	0	0	2	3960
PEDV	0	0	0	0	0	4	4168
APP	0	0	0	0	0	0	3176
SVA	0	0	0	0	0	0	60
Total	53	1575	11,229	23,789	28,108	32,603	41,423

* Iowa State University, South Dakota State University, and University of Minnesota.
ELISA = enzyme-linked immunosorbent assay; PRRSV = porcine reproductive and respiratory syndrome virus; MHP = *Mycoplasma hyopneumoniae*; IAV = influenza A virus; PEDV = porcine epidemic diarrhea virus; APP = *Actinobacillus pleuropneumoniae*; SVA = Senecavirus A.

Table 4: Number of oral fluid specimens submitted for nucleic acid sequencing in 3 US veterinary diagnostic laboratories from 2010 to 2016*

Pathogen	2010	2011	2012	2013	2014	2015	2016
PRRSV	300	919	1444	1223	893	1524	1718
IAV	37	110	522	650	327	433	465
PCV2	0	0	6	7	7	34	8
PEDV	0	0	0	0	34	3	2
Other	0	0	23	27	1	4	10
Total	337	1029	1995	1907	1262	1998	2203

* Iowa State University, South Dakota State University, and University of Minnesota.
PRRSV = porcine reproductive and respiratory syndrome virus; IAV = influenza A virus; PCV2 = porcine circovirus type 2; PEDV = porcine epidemic diarrhea virus.

Senecavirus A

For SVA, 3,598 oral fluid-based tests have been conducted (Tables 1, 2, and 3). Senecavirus A detection in oral fluids has been documented under field conditions.[28] Although no clinical signs were observed, SVA was detected by RT-PCR in oral fluid samples at day zero in one of the sites. The fact that 9 of 10 serum samples were SVA positive on the same farm supported the validity of the oral fluid results. Little peer-reviewed research is available on SVA, but this initial report suggests oral fluids may be a useful sample for monitoring and surveillance of SVA.

Bacterial pathogens

Little research has been done on the detection of bacterial pathogens in oral fluid samples. Regardless, peer-reviewed publications reporting detection by polymerase chain reaction under experimental or field conditions have included the following bacterial agents: APP,[9,62] *Brachyspira* spp.,[63] *Erysipelothrix rhusiopathiae*,[64] *Haemophilus parasuis*,[62] *L intracellularis*,[19] *Mycoplasma* spp.,[20,21,62] *Pasteurella multocida*,[62] *Salmonella*,[19] and *Streptococcus suis*.[62]

Bacterial pathogens for which antibodies are reportedly detected in oral fluids include: APP,[9,10] *E rhusiopathiae*,[64] and *Mycoplasma* spp.[22]

General conclusions

Pig production changed dramatically over the last several decades from smaller single-site farms to larger multisite production systems.[65] These changes made it possible for producers and veterinarians to achieve higher production efficiencies, but also facilitated the appearance of production diseases, ie, multifactorial diseases and the appearance of new, high-impact pathogens, such as PRRSV and PEDV.[66-69]

Diagnostic medicine needs to respond to new disease challenges with new methods capable of providing timely, accurate, informative results. Individual pig samples, such as serum or swabs, have historically served this purpose, but individual animal sampling is not compatible with efficient surveillance in contemporary swine production systems. As an alternative to individual animal samples, Prickett et al[2] described the use of pen-based oral fluid samples (rope testing) for the detection of PRRSV and PCV2 in growing pigs. Since this initial report, oral fluid-adapted nucleic acid and antibody tests have been reported for many of the major swine pathogens and oral fluid-based surveillance has been widely adopted by swine veterinarians and swine producers. This process will continue as more and better tests are adapted to the oral fluid matrix.

Nevertheless, there are good reasons to exercise caution. In particular, the peer-reviewed literature has shown that nucleic acid and

antibody assays can be adapted to oral fluids, but the literature has also consistently shown that the procedures need to be carefully modified for optimum performance with the oral fluid matrix.[70,71] Chittick et al[70] and Gibert et al[36] working with PRRSV and Goodell et al[71] working with IAV found significant differences in test performance among RT-PCR protocols offered in veterinary diagnostic laboratories. Once optimum protocols are identified, they should be broadly implemented to achieve reproducibility among diagnostic laboratories. Overall, the development of oral fluid-based testing has changed the way we monitor disease in swine populations. However, careful work on the part of researchers and critical thinking on the part of producers and veterinarians will be needed to fully develop a reliable and robust oral fluid diagnostics system capable of meeting the current and future needs of the swine industry.

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Conflict of interest

None reported.

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* Non-refereed references.

Conversion tables

Weights and measures conversions

Common (US)	Metric	To convert	Multiply by
1 oz	28.35 g	oz to g	28.4
1 lb (16 oz)	453.59 g	lb to kg	0.45
2.2 lb	1 kg	kg to lb	2.2
1 in	2.54 cm	in to cm	2.54
0.39 in	1 cm	cm to in	0.39
1 ft (12 in)	0.31 m	ft to m	0.3
3.28 ft	1 m	m to ft	3.28
1 mi	1.6 km	mi to km	1.6
0.62 mi	1 km	km to mi	0.62
1 in^2	6.45 cm^2	in^2 to cm^2	6.45
0.16 in^2	1 cm^2	cm^2 to in^2	0.16
1 ft^2	0.09 m^2	ft^2 to m^2	0.09
10.76 ft^2	1 m^2	m^2 to ft^2	10.8
1 ft^3	0.03 m^3	ft^3 to m^3	0.03
35.3 ft^3	1 m^3	m^3 to ft^3	35
1 gal (128 fl oz)	3.8 L	gal to L	3.8
0.264 gal	1 L	L to gal	0.26
1 qt (32 fl oz)	946.36 mL	qt to L	0.95
33.815 fl oz	1 L	L to qt	1.1

Temperature equivalents (approx)

°F	°C
32	0
50	10
60	15.5
61	16
65	18.3
70	21.1
75	23.8
80	26.6
82	28
85	29.4
90	32.2
102	38.8
103	39.4
104	40.0
105	40.5
106	41.1
212	100

°F = (°C × 9/5) + 32
°C = (°F - 32) × 5/9

Conversion chart, kg to lb (approx)

Pig size	Lb	Kg
Birth	3.3-4.4	1.5-2.0
Weaning	7.7	3.5
	11	5
	22	10
Nursery	33	15
	44	20
	55	25
	66	30
Grower	99	45
	110	50
	132	60
Finisher	198	90
	220	100
	231	105
	242	110
	253	115
Sow	300	135
	661	300
Boar	794	360
	800	363

1 tonne = 1000 kg
1 ppm = 0.0001% = 1 mg/kg = 1 g/tonne
1 ppm = 1 mg/L