Dried Blood Spots technology for veterinary applications and biological investigations: technical aspects, retrospective analysis, ongoing status and future perspectives

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Abstract
Dried Blood Spots (DBS) technology has become a valuable tool in medical studies, however, in veterinary and biological research DBS technology applications are still limited. Up-to-date no review has comprehensively integrated all the evidence existing across the fields, technologies and animal species. In this paper we summarize the current applications of DBS technology in the mentioned areas, and provide a scope of different types of dried sample carriers (cellulose and non-cellulose), sampling devices, applicable methods for analyte extraction and detection. Mammals, birds, insects and other species are represented as the study objects. Besides the blood, the review considers a variety of specimens, such as milk, saliva, tissue samples and others. The main applications of dried samples highlighted in the review include epidemiological surveys and monitoring for infections agents or specific antibodies for disease/vaccination control in households and wildlife. Besides the genetic investigations, the paper describes detection of environmental contaminants, pregnancy diagnosis and many other useful applications of animal dried samples. The paper also analyses dried sample stability and storage conditions for antibodies, viruses and other substances. Finally, recent developments and future research for DBS technology in veterinary medicine and biological sciences are discussed.

Keywords Dried blood spots · Dried matrix spots · Veterinary diagnostics · Epidemiological surveys · Sero-surveillance · Genetic investigations

Introduction
Preparation and analysis of whole blood and serum dried samples applied on a filter paper attracted attention of research community in the early 60-s and over the course of several years there was a rise of publication activity in human and veterinary medicine subjects. Despite the fact that Dried Blood Spot (DBS) technology today is widely used in medical diagnostics, the practical value of the technology for veterinary and biology is evidently underestimated. In fact, the use of the DBS technology for sampling, storage and dried biosamples analysis for livestock and wildlife animals disease diagnostics is not widely spread and established in veterinary practice, although, the process of obtaining and sampling of animal dried blood samples has been described since the late 50-s and early 60-s of the last century (Adams and Hanson 1956; Karstad et al. 1957; Benson and Mickle 1964; Aldo Gaggero and Sutmöller 1965; Nobuto 1966). Over the next thirty years, this technology had not drawn much attention neither in veterinary medicine, nor in biological and ecological research. It can be noted that only since 90-s and early 2000-s, along with widespread use of the DBS technology in many research areas, the number of scientific publications concerning DBS technology began to grow (Fig. 1). However, the number of articles on DBS in veterinary and biology is still limited, and only about two hundred seventy papers in total have been published since late 50-s. During the last 10–15 years, the number of veterinary publications in DBS area did not exceed 10–20 papers per year, despite the rapid growth of general publication activity in DBS technology (Fig. 1b). Currently, DBS technology is the principal tool in neonatal screening for the rare genetic diseases detection; it is also extensively used in various medical bioanalytical studies, preclinical drug
trials, toxicokinetic and pharmacokinetic studies, clinical pharmacology, also in forensic, doping, ecological expertise, and biobanking (Demirev 2013; Meesters and Hooff 2013; Sharma et al. 2014; Enderle et al. 2016; Antunes et al. 2016; Lim 2018; McClendon-Weary et al. 2020). Today DBS technology is not limited to whole blood as primarily assayed biofluid and includes much wider range of utilised dried body fluids such as urine, saliva, milk etc. The general term used for air-dried biosamples on filter paper is Dried Matrix Spots (DMS) (Jacques et al. 2022). DBS technology minimizes invasiveness of blood sampling, reduces animal mortality in preclinical studies. Moreover, dry samples are highly stable, and do not require compliance with the cold chain protocol during transportation. The difference in the
number of medical articles and veterinary/biology articles might be explained by the constant growth of DBS applications in human research and healthcare. Thus, searching scientific databases Freeman et al. (2018) identified 2018 unique analytes measured in DBS samples, among them 50% were classified as small molecule, 33% as large molecule, 15% as nucleic acid, and 2% as element. The authors also emphasized that every common analytical method applied to traditional liquid samples had been applied to DBS samples.

DBS technology definitely has distinct advantages, including simplicity of samples collection in the field, easy and space-efficient storage and delivery, applicability to small volume of biofluids, suspensions, tissues of mammals, birds, insects and other animals. Here we summarize scientific data concerning DBS technology application in veterinary medicine and biological investigations in terms of collection, shipment, storage and analysis of dried biosamples by various analytical methods.

**DBS in veterinary and biology: living objects under investigation**

DBS technology has been used for samples collection and analysis in livestock, poultry, pets and in a big variety of domestic, peridomestic and wildlife mammals and birds (Table 1). Dried samples from amphibians, crustaceans, fishes, molluscs, reptiles as well insects have also been taken and investigated (Table 1). Large-scale epidemiological surveys usually included collection of dried samples from a great variety of animals. Thus, the presence of antibodies to *Yersinia pestis* was investigated in DBS samples taken from coyotes, bobcats, striped skunks, raccoons, American badgers, vultures, rats, California voles (Wolff and Hudson 1974); gray and red foxes, gray wolves, mountain lions (Chandler et al. 2018). The investigation of wild rodents (terraced rice rats, Spix’s yellow-toothed cavies, hairy-tailed bolo mice, red-nosed mice, common punarés) and synanthropic rodents (rats) from an endemic area of cutaneous and visceral leishmaniasis in Brazil was described by Oliveira et al. (2005). Blood and tissues from many other vertebrates alone with Australian pelicans, crested pigeons, Mallee fowls, sleepy lizards and fishes (King George Whiting, tuna), frogs, yabbies (an Australian fresh water crustacean), abalones and blue swimmer crabs were investigated by Smith and Burgoyne (2004). Domestic, synanthropic and wild mammals including dogs, donkeys, common opossums, mules, black rats, horses, fruit-eating bats, cats, wild boars, goats, red-tailed squirrels were surveyed for *Trypanosoma cruzi/Leishmania* spp coinfection (Viettri et al. 2018). Herrera et al. (2005) estimated the *Trypanosoma evansi* infection rate and epizootic status of wild and domestic mammals (equines, dogs, bats, feral pigs, peccaries, coatis), small mammals including opossums, agoutis, spiny rats, murids from the Brazilian Pantanal region. *Trypanosoma* infection control usually included blood testing of domestic and wild animals such as horses, pigs, dogs, bovine, buffalo, zebu cattle, capybaras, coatis (Ventura et al. 2001, 2002), as well as cattle together with tsetse flies (Gillingwater et al. 2010).

**Dried samples to analyse**

Application of DBS technology in veterinary and biology is not only limited to whole blood, serum and plasma (Table 1). Other blood fraction, buffy coat, applied and dried on paper, was described as a useful tool for detection of *Trypanosoma*, a blood parasite (Picozzi et al. 2002; Geyser et al. 2003; Gillingwater et al. 2010; Moti et al. 2014). Picozzi et al. (2002) noted that buffy coat preparations on filter paper matrices was the most sensitive methodology relative to the gold standard than analysis of liquid whole blood or dried whole blood for PCR determination of *T. brucei* in domestic livestock. Specific tasks in veterinary and biological research also employed a wide range of dried biosamples such as milk (Wu et al. 2008; Samsonova et al. 2014, 2017; Durel et al. 2015; Venkatesh and Gopal 2018), serosanguineous fluid from the thoracic cavity (Elmore et al. 2014), spleen and lymph node aspirates (Strauss-Ayali et al. 2004), tongue epithelial (Muthukrishnan et al. 2008; Madhanmohan et al. 2013, 2016; Biswal et al. 2016) and foot epithelium samples (Madhanmohan et al. 2016), brain tissue spots (Wacharapluesadee et al. 2003; Jefferies et al. 2007; Sakai et al. 2015; Léchenne et al. 2016; Rasolonjatoovo et al. 2020), bone marrow aspirates (Cortes et al. 2004), bovine semen (Sarangi et al. 2018), haemolymph (Machado et al. 2000; Kiaptathamchai et al. 2004; Sudhiakaran et al. 2009), fish body mucus and buccal cells (Lucentini et al. 2006), ray mucus (Kashiwagi et al. 2015), lavral homogenate and milt (Navaneeth Krishnan et al. 2016) and a big variety of tissue and swab samples (Table 1). Insect dried samples used for analysis included insects crash (Lall et al. 2010; Dickey et al. 2012) or suspension/homogenate (Snowden et al. 2002; Harvey 2005; Desloire et al. 2006), dry fecal spots (Russomando et al. 1996; Machado et al. 2000; Dorn et al. 2001; Brito et al. 2008; Braz et al. 2008), haemolymph (Machado et al. 2000), gut smear (Boid et al. 1999; Adams et al. 2006; Fall et al. 2012), midgut and proboscises (Gillingwater et al. 2010), crashed abdomen (Niare et al. 2017), blood meal specimens (Reeves et al. 2016) and saliva (Hall-Mendelin et al. 2010; van den Hurk et al. 2014; Flies et al. 2015; Johnson et al. 2015; Burkett-Cadena et al. 2016; Kurucz et al. 2014; 2019; Wipf et al. 2019; Birnberg et al. 2020). In some cases, insect nucleic acids were first extracted and then stored on the paper in a dried form (Owens and Szalanski 2005; Bujang et al. 2011; Miller et al. 2013).
| Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|---------------|------------|---------|--------------|----------------|-----------|
| Cattle, camels, horses | **Infectious disease diagnostics** | | | | |
| **Bluetongue disease** (bluetongue virus) | Cattle, sheep | ELISA | Antibodies | Whole blood | Whatman no.4 filter paper | Afshar et al. 1987 |
| | Cattle | Blocking dot ELISA, ELISA | | | Whatman filter paper | Afshar et al. 1992 |
| **Bovine babesiosis** (*B. bigemina*) | Cattle | IFA test | Antibodies | Whole blood | Whatman no.4 filter paper | Burridge et al. 1973 |
| | | | | | Whatman no.1 filter paper | Singh et al. 2009 |
| **Bovine babesiosis** (*B. bigemina* and *B. argentina*) | | | | Filter paper | Todorovic and Garcia 1978 |
| **Bovine leucosis** (bovine leucosis virus) | Cattle | PCR | DNA | Whole blood | Filter paper | Young and Purnell 1980 |
| **Bovine leucosis** (bovine leucosis virus), **bovine viral diharrhoea** (BVD virus), **infectious bovine rhinotracheitis** (bovine herpes-virus-1) | Cattle | ELISA, PCR | Antibodies, cDNA | Whole blood | Fiberglass strip | Saushkin et al. 2016a, b, 2019 |
| **Bovine mastitis** (*Strep. agalactiae*) | Cattle | PCR | DNA | Milk | Xinhua grade 3 chr paper treated with EDTA | Wu et al. 2008 |
| **Bovine mastitis** (*S. aureus, Strep. agalactiae* and *M. bovis*) | | | | FTA card | Durel et al. 2015 |
| **Bovine respiratory disease complex** (bovine viral diarrhea virus, bovine respiratory syncytial virus, bovine coronavirus, bovine herpesvirus-1) | Cattle | PCR | DNA, RNA | Diagnostic swab fluids, deep nasal swabs | FTA card | Liang et al. 2014 |
| **Bovine viral diharrhoea** (BVD virus) | Cattle | RT-PCR | RNA | Whole blood, serum | Filtration paper, Whatman no.1 filter paper, nitrocellulose no.71002, HYBOND-M nylon | Vilček et al. 2001 |
| **Brucellosis** (*B. abortus*) | Cattle | ELISA | Antibodies | Whole blood | Whatman no.5 filter paper | McLean and Hilbink 1989 |
| **Cystic echinococcosis** (*Echinococcus granulosus sensu lato*) | Cattle, camel, sheep, goat | PCR, sequencing | DNA | Germinal layer of cysts from liver, lung or intestines | FTA card | Boué et al. 2017 |
**Table 1** (continued)

| Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|-------------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| *East Cost fever (Theileria parva)*              | Cattle        | IFA test   | Antibodies | Whole blood   | Filter paper   | Kimber and Burridge 1972 |
| *Eastern equine encephalomyelitis* (EEE virus)   | Horse, wild birds | Virus neutralization test | Antibodies | Whole blood, serum | Filter paper discs | Karstad et al. 1957 |
| *Foot-and-mouth disease (FMD virus)*             | Cattle        | Virus neutralization test, mouse protection test | Antibodies | Whole blood, serum | Blotting paper strip | Aldo Gaggero and Sut-möller 1965 |
|                                                 |               | ELISA      | Serum     |               | Fiberglass strip | Samsonova et al. 2019b |
|                                                 |               | RT-PCR     | RNA       | Cell culture virus, tongue epithelium | FTA card | Muthukrishnan et al. 2008 |
|                                                 |               | RT-LAMP    | RNA       | Tongue epithelium |               | Madhanmohan et al. 2013 |
|                                                 |               | RT-PCR, qRT-PCR, RT-LAMP | RNA       | Cell culture virus, tongue and foot epithelium |               | Madhanmohan et al. 2016 |
| *Hemoprotozoan parasites (piroplasms and trypanosomes)* | Camel | PCR, sequencing | DNA | Whole blood | FTA card | Sazmand et al. 2016 |
| *Infectious bovine rhinotracheitis* (bovine herpesvirus-1) | Cattle | ELISA | Antibodies | Whole blood, serum | Whatman no.3 filter paper (strips) | de Oliveira et al. 2011 |
| *Rabies* (rabies virus)                         | Cattle, horse | RT-PCR | DNA | Bovine semen | FTA card | Sanagi et al. 2018 |
| *Tropical theileriosis (Theileria annulata)*     | Zebu, cross bred cattle (zebu x Friesian) | PCR | DNA | Brain tissue | FTA card | Sakai et al. 2015 |
| *Trypanosomosis (T. brucei, T. congolense, T. vivax)* | Cattle | IFA test | Antibodies | Whole blood | Whatman no.4 filter paper | Ashkar and Ochilo 1972 |
| *Trypanosomosis (T. vivax)*                     |               | ELISA      |          |               |                | Platt and Adams 1976 |
| *Trypanosomosis (T. brucei, T. congolense, T. vivax)* |               | ELISA      |          |               | Whatman no.1 filter paper | Hopkins et al. 1998 |
| *Trypanosomosis (T. evansi)*                    | Water buffalo |          |          |               |                | Holland et al. 2002 |
Table 1 (continued)

| *Infection/causative agent/aim of the investigation | Living object | **Method | Analyte | Dried sample | Sample carrier | Reference |
|----------------------------------------------------|---------------|----------|---------|--------------|----------------|-----------|
| Trypanosomosis (T. congolense and T. brucei)       | Cattle        | PCR      | DNA     | Whole blood  | Whatman no.4 filter paper | Katakura et al. 1997 |
| Trypanosomosis (T. vivax)                         |               |          |         |              | Whatman no.4 filter paper | Ventura et al. 2001 |
| Trypanosomosis (T. vivax, T. evansi)              |               |          |         |              | Filter paper         | Gonzales et al. 2003 |
| Trypanosomosis (T. brucei)                        |               |          |         |              | Filter paper, FTA card | Gonzales et al. 2006 |
| Trypanosomosis (Trypanosoma species)              |               |          |         |              | FTA card           | Picozzi et al. 2002 |
| Trypanosomosis (T. vivax, T. evansi)              |               |          |         | Whole blood  | Whatman no.4 filter paper | Coelho et al. 2005 |
| Trypanosomosis (T. congolense)                    | Cattle        | PCR–RFLP | DNA     | Buffy coat   | Whatman no.4 filter paper | Vitouley et al. 2011 |
| Trypanosomosis (Trypanosoma species)              | Cattle, goat  | PCR–RFLP | DNA     | Buffy coat   | Whatman no.3 filter paper | Geytenbeek et al. 2003 |
| Trypanosomosis (T. congolense)                    | Cattle, tsetse fly | PCR        |         | Buffy coat (cattle), midgut and proboscis (tsetse fly) | FTA Elute card | Gillingwater et al. 2010 |
| Trypanosomosis (T. vivax, T. evansi)              | Cattle, buffalo, sheep |          |         | Whole blood  | Whatman no.4 filter paper | Dávila et al. 2003 |
| Trypanosomosis (T. vivax, T. congolense, T. brucei) | Zebu          |          |         |              | FTA card           | Cox et al. 2010 |
| Trypanosomosis (T. brucei)                        | Cattle, pig, sheep, goat |          |         |              | TEGO card           | de Clare Bronsvoort et al. 2010 |
| Trypanosomosis (T. evansi)                        | Camel         |          |         |              | Fiberglass strip    | Salim et al. 2011 |
| Other investigations                              |               |          |         |              |                 |           |
| Pregnancy diagnosis                               | Cattle        | ELISA    | Pregnancy-associated glycoproteins (PAGs) | Whole blood | TEGO card | Sun et al. 2013 |
|                                                   |               |          | Progesterone | Milk           | Fiberglass strip    | Samsonova et al. 2014, 2017 |
| *Infection/causative agent/aim of the investigation | Living object | **Method | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------|---------------|----------|---------|-------------|---------------|-----------|
| Casein genotyping (A1/A2 variants of β-casein)     | Cattle        | PCR      | DNA     | Milk, whole blood | Whatman no.3 filter paper treated with SPGA-EDTA buffer (milk) FTA card (blood) | Venkatesh and Gopal 2018 |
| Evaluation of the nutritional status of ranging dairy cows | Zebu | ESI–MS/MS | Amino acids, acylcarnitines | Serum | Whatman 903 card | Worku et al. 2021 |
| Atypical myopathy (inhibited β-oxidation of fatty acids) | Horse | ESI–MS/MS | Acyl carnitines | Serum | Munktell filter paper cards | Sander et al. 2018 |
| Antidoping race control (anabolic steroids, β2-adrenoceptor agonists, corticosteroids, HIF-1 stabilizers, PPAR δ agonists, SARMs, and aromatase inhibitors) | Horse | LC–MS/MS | 50 analytes | Whole blood | Whatman 903 card | Moeller and Yang 2021 |

**Small cattle**

**Infectious disease diagnostics**

| *Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------|---------------|----------|---------|-------------|---------------|-----------|
| Toxoplasmosis (*T. gondii*) | Sheep | DIG-ELISA | Antibodies | Whole blood | Munktell 1300 filter paper | Uggl and Nilsson 1987 |
| | Sheep, goat | ELISA, IFA test | Serum | | Whatmann no.4 filter paper | Al-Kappany et al. 2018 |
| Trypanosomosis (*Trypanosoma spp.*) | Goat | PCR | DNA | Whole blood | | de Almeida et al. 1997, 1998a, b |
| Trypanosomosis (*T. congolense, T. vivax, T. brucei*) | Goat | ELISA, latex agglutination | Antibodies | Whole blood, serum | Fiberglass strip | Saushkin et al. 2018 |

**Other investigations**

| *Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------|---------------|----------|---------|-------------|---------------|-----------|
| Molecular detection and genotyping of Peste des petits ruminants virus | Goat | RT-PCR; sequencing | RNA | Whole blood, nasal swabs | Whatman 3MM filter paper | Bhuian et al. 2014 |

**Swine**

**Infectious disease diagnostics**

| *Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------|---------------|----------|---------|-------------|---------------|-----------|
| African swine fever (ASF virus) | Pig | PCR, sequencing | DNA | Whole blood | FTA card | Utenthal et al. 2013 |
| | | PCR, ELISA | DNA, antibodies | | Whatman 3MM filter paper (stripes) | Randriampanarany et al. 2014 |
| Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|-----------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| Aujeszky’s disease (AD virus)                  | Pig           | ELISA      | Antibodies | Whole blood  | Whatman no.1 filter paper | Banks 1985 |
|                                               |               |            |          |              | Filter paper    | Motha et al. 1987 |
|                                               |               | Virus neutralization test, ELISA | Antibodies | Whole blood, serum | Whatman no.113 filter paper | Armstrong et al. 1991 |
| Foot-and-mouth disease (FMD virus)             | Pig           | ELISA      | Antibodies | Whole blood  | Filter paper    | Motha et al. 1987 |
|                                               |               | ELISA, RT-PCR | Antibodies, RNA | Whole blood  | TEGO Card   | Armstrong et al. 1991 |
| Porcine reproductive and respiratory syndrome (PRRS virus) | Pig         | RT-PCR     | RNA       | Whole blood  | Filter paper    | Spagnuolo-Weaver et al. 1998 |
|                                               |               |            |          | Whole blood  | FTA card | Inoue et al. 2007 |
|                                               |               |            |          | Whole blood, serum, organs (lung, tonsil, and superficial inguinal lymph nodes), oral fluid | | Linhares et al. 2012 |
| Swine influenza (swine influenza virus)         | Pig           | RT-PCR     | RNA       | Allantoic fluid, nasal swabs, lung tissue | FTA card | Maldonado et al. 2009 |
| Swine vesicular disease (SVD virus)            | Pig           | ELISA      | Antibodies | Whole blood  | Filter and blotting paper | Hamblin and Hedger 1982 |
| Toxoplasmosis (T. gondii)                      | Pig           | HA test    | Antibodies | Whole blood  | Nobuto filter paper strip | Nobuto 1966 |
| Vesicular stomatitis (VS virus)                | Pig           | Virus neutralization test | Antibodies | Serum | Blotting paper | Adams and Hanson 1956 |

Other investigations
- Pregnancy diagnosis
- Genotyping and phylogenetic analysis of African swine fever virus, Peste des petits ruminants virus
- Extraction of DNA for genomic analysis
- Determining of optimal dietary intake of nutrients

Poultry
Infectious disease diagnostics
| *Infection/causative agent/aim of the investigation | Living object | **Method | Analyte | Dried sample | Sample carrier | Reference |
|--------------------------------------------------|--------------|----------|-------|-------------|---------------|-----------|
| Avian infectious bronchitis (infectious bronchitis virus) | Chicken | ELISA | Antibodies | Whole blood | Whatman no. 1 filter paper (strips) | Lana et al. 1983 |
|                                                    |             | RT-PCR, RFRP, sequencing | RNA | Tracheal swabs | FTA card | Moscoso et al. 2005 |
| Avian influenza (avian influenza virus)           | Chicken, wild birds | RT-qPCR | RNA | Swab samples | FTA card | Abdelwhab et al. 2011 |
|                                                    | Chicken     | RT-PCR | RNA | Cloacal and oropharyngeal swabs, lungs, spleen, kidneys, and brain | FTA card | Jóźwiak et al. 2016 |
| Avian influenza (avian influenza virus), Newcastle disease (Newcastle disease virus) | Chicken | HI test | Antibodies | Whole blood | Filter paper | Brugh and Beard 1980 |
|                                                    | Poultry (chicken, turkey, guinea fowl, duck, goose) | RT-PCR | RNA | Oropharyngeal swabs | FTA card | Shekaili et al. 2015 |
| Avian metapneumovirus infection (avian metapneumovirus) | Chicken | RT-PCR | RNA | Turbinate, trachea and lung | FTA card | Awad et al. 2014 |
| Fowl adenovirus I detection and genotyping        | Chicken | PCR | DNA | Liver | FTA card | Moscoso et al. 2007 |
| Fowl cholera (P. multocida)                        | Chicken | ELISA | Antibodies | Whole blood | Schleicher & Schuell no.740-E filter paper (strips) | Avakian and Dick 1985 |
| Fowl typhoid and paratyphoid                      | Chicken | ELISA | Antibodies | Whole blood | Filter paper | Minga et al. 1992 |
| Fowl typhoid and Salmonella enteritidis           | Chicken | ELISA | Antibodies | Whole blood | Filter paper | Minga and Wray 1992 |
| Hepatitis B (duck hepatitis virus)                | Duck       | PCR | DNA | Serum | Whatman no.1 filter paper, nitrocellulose no.71002, HYBOND-M nylon | Wang et al. 2002 |
| Infectious bursal disease (infectious bursal disease virus) | Chicken | Agar gel precipitation test | Antibodies | Whole blood | Whatman no.1 filter paper (strips) | Roy et al. 1994 |
|                                                    |             | QAGP test |             | | | Thangavelu et al. 2000 |
|                                                    |             | ELISA | Serum | | Whatman no.1 filter paper | Ahmed et al. 2012 |
|                                                    |             | RT-PCR | RNA | Bursa | FTA card | Moscoso et al. 2006 |
|                                                    |             |             | | | Chromatography paper, filter paper, stationery copy paper, FTA card | Maw et al. 2006 |
| **Infection/causative agent/aim of the investigation** | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------------|---------------|------------|---------|-------------|---------------|-----------|
| *Infection*/*causative agent*/*aim of the investigation** | **Living object** | **Method** | **Analyte** | **Dried sample** | **Sample carrier** | **Reference** |
| Infectious bursal disease (infectious bursal disease virus), avian infectious bronchitis (infectious bronchitis virus), micoplasmosis (M. gallisepticum and M. synoviae) | Chicken | ELISA | Antibodies | Whole blood, serum | Fiberglass strip | Samsonova et al. 2019a |
| Marek's disease (Marek’s disease virus) | Chicken | PCR | DNA | Whole blood, solid tumors | FTA card | Cortes et al. 2009 |
| Micoplasmosis (M. gallisepticum and M. synoviae) | Chicken | PCR, RFRP, sequencing | DNA | Tracheal swabs | FTA card | Moscoso et al. 2004 |
| Newcastle disease (Newcastle disease virus) | Chicken | HI test | Antibodies | Whole blood | Nobuto filter paper strip | Beard and Brugh 1977 |
| | | | | | Whatman no.1 filter paper | Roy et al. 1997 |
| | | | | | Whatman no.1 filter paper (strips) | Roy et al. 1992 |
| | | RT-PCR | RNA | Trachea, lung, caecal tonsil and cloacal faeces | FTA card | Perozo et al. 2006 |
| | | | | Caecal tonsils, kidney, proventriculus, spleen, trachea, faecal swabs and intestinal lesions | | Narayanan et al. 2010 |
| | Western equine encephalomyelitis (WEE virus), St. Louis encephalitis (SLE virus) | Chicken | ELISA | Antibodies | Whole blood | Whatmann no.1 filter paper (strips) | Reisen et al. 1994 |
| Other investigations | | | | | | |
| Antibiotic detection | Chicken | LC | Enrofloxacin, ciprofloxacin | Whole blood | Filter paper | Posyniak et al. 2002 |
| Determination of avian sexing | Chicken | PCR | DNA | Whole blood | FTA Elute card, FTA card, Whatman 903 card, Whatman grade 1 filter paper, office paper | Suriyaphol et al. 2014 |
| Genotyping of infectious bronchitis virus | Chicken | RT-PCR, sequencing | RNA | Tissues of trachea, lung, kidney and caecal tonsil | FTA card | Ganapathy et al. 2015 |
| | | | | Tissues and swab samples | | Mansur et al. 2018 |
| | | | | Tissues of trachea, pharynx, caecal tonsil, kidney and turbinate | | Ball et al. 2016 |
### Table 1 (continued)

| *Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|----------------------------------------------------|----------------|------------|---------|--------------|----------------|-----------|
| **Pets**                                           |                |            |         |              |                |           |
| **Infectious disease diagnostics**                 |                |            |         |              |                |           |
| Canine babesiosis *(B. gibsoni)*                   | Dog            | PCR        | DNA     | Whole blood  | Whatman 3MM filter paper | Tani et al. 2008 |
| Canine distemper (CD virus), infectious canine hepatitis (canine adenovirus 1), leptospirosis *(Leptospira spp.)* | Dog            | Virus neutralization test | Antibodies | Whole blood  | Borosilicate filter paper no.934-AH | Benson and Mickle 1964 |
| Canine visceral leishmaniasis *(L. donovani)*      | Dog            | IFA test   | Antibodies | Whole blood  | Filter paper | Evans et al. 1990, Cabrera et al. 1999, da Silva et al. 2000, Figueiredo et al. 2010a, b |
|                                                    |                | DAT        |          |              | Whatman no.4 filter paper | Kalayou et al. 2011 |
|                                                    |                | ICT        | Plasma   | Bone marrow aspirates, whole blood | HemaSpot device | Rosypal et al. 2014, Cortes et al. 2004 |
|                                                    |                | PCR        | DNA      | Spleen or lymph node aspirates, whole blood | Whatman no.3 filter paper | Filter paper | Strauss-Ayali et al. 2004 |
| **Dirofilariaasis (D. repens)**                    | Dog            | qPCR       | DNA      | Whole blood  | Whatman FTA Elute card | Duscher et al. 2009, Nogami et al. 1992 |
| **Toxoplasmosis (T. gondii)**                      | Cat            | Latex agglutination test | Antibodies | Whole blood  | Quantitative filter paper strips (Toyo Roshi Kaisha) | Bolais et al. 2017, Umeakuana et al. 2019 |
| **Trypanosomosis (T. brucei gambiense)**           | Dog            | MAT        | DNA      | Whole blood  | Whatman 903 card | FTA card | Jefferies et al. 2007 |
| **Piroplasmosis** *(piroplasm spp.)*               | Dog            | PCR–RFLP   | DNA      | Whole blood  | FTA classic card (cut into strips) and IsoCode stix | Schleicher and Schuell no. 903 filter paper | Wacharapluesadee et al. 2003, Léchenne et al. 2016 |
| **Rabies** *(rabies virus)*                        | Dog            | RT-PCR, NASBA | RNA      | Brain tissue | Schleicher and Schuell no. 903 filter paper | FTA card | Wacharapluesadee et al. 2003, Léchenne et al. 2016 |
|                                                    |                | RT-qPCR    |          |              |                |           |
| **Other investigations**                           |                |            |         |              |                |           |
| Genotyping of dog leukocyte antigen                | Dog, wolf      | PCR, sequencing | DNA     | Whole blood  | Whatman FTA Elute card | Kennedy et al. 2008 |
| Control of immune-mediated and allergic disorders   | Cat            | HPLC–ESI–MS/MS | Cyclosporin A | Whole blood  | Whatman 903 card | Mohamed et al. 2012 |
| Living object                  | **Method**          | Analyte                           | Dried sample | Sample carrier | Reference                  |
|-------------------------------|---------------------|-----------------------------------|--------------|----------------|----------------------------|
| Lysosomal storage disease     | Fluorescent method  | Lysosomal enzymes activity        | Whole blood  | Munktell TFN 06–079 card | Sewell et al. 2012          |
| Determination of the prevalence of vector-borne pathogens (*Rickettsia* spp., *Anaplasma*aceae, *Bartonella* spp. and *Babesia* spp) | PCR                 | DNA                              | Whole blood  | FTA card               | Probose et al. 2015         |
| Telomere length assessment    | qPCR                | DNA                              | Whole blood  | FTA card               | Dutra et al. 2020           |
| Wild and domestic animals (mammals and birds) | ELISA               | Antibodies                       | Whole blood  | 12-spot DBS card (comb) | Dam-Tuxen et al. 2014; Knuuttila et al. 2014 |
| *Aleutian disease* (Aleutian disease virus) | ELISA               | Antibodies                       | Whole blood  | Munktell TFN filter paper | Anderson et al. 2015, 2016, 2017 |
| *Avian influenza* (avian influenza virus) | ELISA               | Antibodies                       | Whole blood  | Nobuto filter paper strips | Dusek et al. 2011          |
| *Bluetongue disease* (bluetongue virus), *hemorrhagic disease* (hemorrhagic disease virus) | White-tailed deer   | Virus neutralisation test, AGID  | Whole blood  | Schleicher & Schuell no.740E filter paper (stripes) | Stallknecht and Davidson 1992 |
| Sero-prevalence of *bluetongue disease* (bluetongue virus), *hemorrhagic disease* (hemorrhagic disease virus) | Mule deer           | Virus neutralisation test         | Whole blood  | Dubay et al. 2006      |
| *Bovine tuberculosis* (*M. bovis*) | ELISA               | Antibodies                       | Whole blood  | Whatman 903 card, FTA card | Santos et al. 2018          |
| Sero-prevalence of *brucellosis* (*B. abortus*) | ELISA               | Antibodies                       | Whole blood  | Nobuto filter paper strips | Curry et al. 2011          |
| *Brucellosis* (*B. abortus*) | PFIA                |                                   |              |                | Jennings-Gaines et al. 2021 |
| Assessment of exposer to *Brucella abortus*, *Neospora caninum*, *West Nile virus*, *herpes virus*, *bovine parainfluenza virus*, *bovine respiratory syncytial virus*, *bovine viral diarrhea virus* | ELISA; virus neutralisation test | Antibodies | Whole blood  | Nobuto filter paper strips | Curry et al. 2014b          |
| Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|--------------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| Sero-prevalence of canine distemper virus, canine parvovirus type 2, and canine adenovirus type 1 | Wolverines | IFA | Antibodies | Whole blood | Nobuto paper strip | Dalerum et al. 2005 |
| Canine distemper (canine distemper virus), canine parvovirus disease (canine parvovirus) | Coyote, raccoon | Virus neutralization test; HI test | Antibodies | Whole blood | Nobuto filter paper strips | Kamps et al. 2015 |
| Sero-prevalence of cat scratch disease – bartonellosis (B. henselae) | Puma, bobcat Mountain lion, bobcat | IFA test | Antibodies | Whole blood | Nobuto filter paper strips | Chomel et al. 2004 Yamamoto et al. 1998 |
| Sero-prevalence of Bartonella vinsonii subsp. berkhoffii | Coyote | ELISA | Whole blood | Nobuto filter paper strips | Chang et al. 1999 |
| Cytauzoonosis (C. felis) | Bobcat | PCR | DNA | Whole blood | Nobuto filter paper strips | Birkenheuer et al. 2008 |
| Canine heartworm disease – dirofilariasis (D. immitis) | Coyote | ELISA | Antibodies | Whole blood | Nobuto filter paper strips | Sacks et al. 2002 |
| Investigation of Ehrlichia spp. occurrence | Coyote | PCR | DNA | Whole blood | Nobuto filter paper strips | Pusterla et al. 2000 |
| Sero-prevalence of Ehrlichia chafeensis | White-tailed deer | IFA | Antibodies | Whole blood | Nobuto filter paper strips | Mueller-Amneling et al. 2000 |
| Sero-prevalence of hepatitis E (hepatitis E virus) | Sika deer | ELISA | Antibodies | Whole blood | Whatman filter paper discs | Yu et al. 2007 |
| Sero-prevalence of louping-ill virus | Willow ptarmigan | HI test | Antibodies | Whole blood | Nobuto filter paper strips | Ytrehus et al. 2021 |
| Lyme disease (B. burgdorferi), anaplasmosis (A. phagocytophilum), ehrlichiosis (E. canis), canine heartworm disease – dirofilariasis (D. immitis) | Grey wolf | ELISA (SNAP 4Dx test) | Antibodies | Serum | Nobuto filter paper strips | Jara et al. 2015 |
| Assessment of exposer to Neospora caninum, West Nile virus, herpes virus, bovine parainfluenza virus, bovine respiratory syncytial virus, bovine viral diarrhea virus | Reindeer | ELISA; virus neutralization test | Antibodies | Whole blood | Nobuto filter paper strips | Curry et al. 2014a |
| Pigeon circovirus infection (pigeon circovirus) | Pigeon | PCR | DNA | Whole blood | Filter paper | Hattermann et al. 2002 |
Table 1 (continued)

| Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|--------------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| **Plague** (*Y. pestis*)                          | Small rodents, carnivores | HA test | Antibodies | Whole blood, serum | Nobuto filter paper strips | Wolff and Hudson 1974 |
|                                                  | Coyote, raccoon, canids, felids | HI test; a bead-based flow cytometric serodiagnostic assay (Luminex) | Whole blood | | | Chandler et al. 2018 |
| **Assessment of plague** (*Y. pestis*) exposure  | Coyote | ICT | | | | Abbott et al. 2014 |
| **Rabies** (rabies virus)                        | Red fox, raccoon dog | ELISA | Antibodies | Whole blood | Trans-blot filter paper, BioRad | Wasniewski et al. 2014 |
| **Assessment of prevalence of reticuloendotheliosis virus** | Wild animals | RT-hn-PCR | RNA | Brain tissue | Whatman 903 filter paper | Rasolonjatovo et al. 2020 |
| **Sarcocytosis** (*S. falcatula*)                 | Thick-billed parrot | PCR | DNA | Whole blood | FTA card | Rivas et al. 2021 |
| **Sero-prevalence of Sendai virus, mouse hepatitis virus** | Mice | ELISA | Antibodies | Whole blood | Filter paper discs (Advance Toyo) | Katakura et al. 1992 |
| **Sero-prevalence of toxoplasmosis** (*T. gondii*), sarcocytosis (*S. neurona*) | Beaver | MAT | Antibodies | Whole blood | Filter paper | Jordan et al. 2005 |
| **Toxoplasmosis** (*T. gondii*)                   | Zoo animals (mammals and birds) | Indirect HA test | Antibodies | Whole blood | Schleicher & Schuell no.589 filter paper | Ippen et al. 1981 |
| **Sero-prevalence of Toxoplasma gondii**          | Bobcat | MAT | | | Nobuto filter paper strips | Mucker et al. 2006 |
|                                                  | Domestic and peri-domestic rodents | | | | Guthrie card | Mercier et al. 2013 |
|                                                  | Ungulates (tapir, peccary, brocket deer) | | | | Whatman 903 card, FTA card, cellulose filters grade 2 and 3 | Aston et al. 2014 |
|                                                  | Arctic-nesting geese | IFA test, direct agglutination test | Serosanguineous fluid from the thoracic cavity | | Nobuto filter paper strips | Elmore et al. 2014 |
|                                                  | Wolverines | MAT, ELISA, IFA test | Whole blood | | | Sharma et al. 2019 |
| *Infection/causative agent/aim of the investigation | Living object | **Method | Analyte | Dried sample | Sample carrier | Reference |
|---|---|---|---|---|---|---|
| Trypanosomosis (*T. evansi*) | Wild and domestic animals (horse, pig, dog, bovine, buffalo, capybara, coatis) | PCR | DNA | Whole blood | Whatman no.4 filter paper | Ventura et al. 2002 |
| | Wild and domestic mammals (equines, dog, bat, feral pig, peccary, coatis and small mammals) | | | | Filter paper confetti | Herrera et al. 2005 |
| Trypanosomosis (*T. cruzi*) | Non-human primates | FTA card | Aysanoa et al. 2017 |
| | Bat | Whatman 3MM filter paper | Villena et al. 2018 |
| | Canine, skunk | Nobuto filter paper strips | Gulas-Wroblewski et al. 2021 |
| Trypanosomosis: diagnosis and genetic analysis | Rat, native rodents | Filter paper | Ortiz et al. 2018 |
| Trypanosomosis and leishmaniasis coinfection (*T. cruzi/Leishmania spp.*) | Domestic, sylvatic and wild mammals | PCR | DNA | Whole blood | Filter paper | Vietti et al. 2018 |
| Tularemia (*F. tularensis*) | Mice, ticks | PCR-EIA | DNA | Whole blood, liver and spleen smears (mice), tick extracts | FTA card | Higgins et al. 2000 |
| Visceral leishmaniasis (*Leishmania spp.*) | Small rodents | PCR-hybridization technique | DNA | Whole blood | FTA card | Oliveira et al. 2005 |
| Sero-prevalence of West Nile virus infection (West Nile virus) | Red-winged blackbird | ELISA | Antibodies | Whole blood | Nobuto filter paper strips | Sullivan et al. 2006 |
| | Ruffed grouse | PRNT | | | | Nemeth et al. 2017; 2021 |
| West Nile virus surveillance | Wild birds (corvid, passerine, raptor, waterfowl) | RT-PCR | RNA | Oral swabs | FTA card, RNASound card | Foss et al. 2016 |
| Genetic studies | Kirtland’s warbler | PCR, sequencing | DNA | Whole blood | FTA card | King et al. 2005 |
| | Monkeys | PCR-based genome walking approach, sequencing | DNA | Whole blood | Whatman filter paper | Sintasath et al. 2009a, b |
| **Infection/causative agent/aim of the investigation** | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|-----------------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| Population genetic and phylogenetic analysis        | Indigenous chickens, Ceylon junglefowl | PCR, sequencing | DNA | Whole blood | FTA card | Silva et al. 2009 |
| Population genetic studies                          | Coyote        | Miscrosatellite genotyping | DNA | Whole blood | Nobuto filter paper strips | Sacks et al. 2004 |
|                                                    | Mallard       | SNP genotyping | DNA | Whole blood | FTA card | Knus et al. 2013 |
|                                                    | Barn swallow  | PCR         | DNA | Whole blood | Whatman filter paper | Guerriini et al. 2014 |
|                                                    | Lemur         | Microsatellite genotyping | DNA | Whole blood | FTA card | Nunziata et al. 2016 |
| Microsatellite genotyping                            | Addax         | PCR         | DNA | Whole blood | FTA card | Heim et al. 2012 |
| Verification of taxonomic identifications in ecological surveys | Opossum, bat, rodents | DNA barcoding | DNA | Liver, heart, other tissues | FTA CloneSaver card | Borisenko et al. 2008 |
| Molecular characterization of piroplasm species (Babesia and Cytauxzoon) | Meerkat | PCR, sequencing | DNA | Whole blood | FTA elute card | LeClaire et al. 2015 |
| Ecological investigations                           | Bottlenose dolphin | ELISA | Brevetoxin | Whole blood | Schleicher and Schuell grade 903 filter paper | Maucher et al. 2007 |
| Exposure to brevetoxin-producing red tides          | Wild birds    | ICP-MS, HRGC-HRMS, LC + ESI-MS/MS | Heavy metals, organochlorine pesticides, toxic organic substances | Whole blood | Schleicher and Schuell no. 903 filter paper | Shlosberg et al. 2011, 2012 |
| Exposure to multiple algal toxins                   | Wild birds    | GC-ECD | Toxic chlorinated hydrocarbons | Whatman 903 card | Lehner et al. 2018 |
| Exposure to environmental contaminants              | Bald eagle, African penguin | GC–MS/MS | Organochlorine pesticides and polychlorinated biphenyls | | Lehner et al. 2020 |
|                                                     | Florida manatee | UHPLC-MS/MS | Per- and polyfluoroalkyl substances | | Griffin et al. 2021 |
| Assessment of toxic heavy metals exposure           | Eagle, cat, crocodile | ICP-MS | Toxic heavy metals | Whole blood | Whatman 903 card | Lehner et al. 2013 |
Table 1 (continued)

| *Infection/causative agent/aim of the investigation | Living object | **Method | Analyte | Dried sample | Sample carrier | Reference |
|---------------------------------------------------|---------------|----------|---------|--------------|----------------|-----------|
| Monitoring mercury concentration in wildlife population | Marine mammals (bottlenose dolphin, harbor seal) | AAS | Mercury | Whole blood | Nobuto filter paper strips | Hansen et al. 2014 |
| Risk assessment of mercury concentration | Pinnipeds (northern elephant seal, harbor seal, California sea lion) | | | | | McHaron et al. 2019 |
| Assessment of mercury exposure | Wild birds (zebra finch, American golden-clover) | | | | | Perkins and Basu 2018 |

**Other investigations**

| Assessment of feeding ecology or diet studies | Bottlenose dolphin, muskox, wild moose | EA-IRMS | Carbon (C) and nitrogen (N) stable isotopes | Whole blood | Nobuto filter paper strip | O’Hara et al. 2018 |
| Assessment of the vitamin D3 status (metabolic bone disease, MBD) of indoor housed birds | Tropical birds Cornrake | Analysis (LC–MS/MS) was done by City Assays (UK) | 25-Hydroxyvitamin D3 | Whole blood | Whatman 903 filter paper | Drake et al. 2017 |
| The evaluation of vitamin D status | Chimpanzee | LC–MS/MS | 25-hydroxyvitamin D | Whole blood | Whatman 903 filter paper | Moittie et al. 2020 |
| | Hoffmann’s two-toed sloth | | | | | Higgins et al. 2020 |
| Evaluating of circulating fatty acid composition | African savanna elephant Southern white rhinoceros | Analysis (GC) was done by Lipid Technologies, LLC (USA) | Fatty acids | Whole blood | PerkinElmer spot saver card | Wood et al. 2021b |
| | | | | | | Wood et al. 2021c |
| Cholinesterase inhibitors (e.g. organophosphate and carbamate insecticides) | Wild birds | Spectrophotometric method | Cholinesterase activity | Whole blood | Whatman no.4 filter paper | Trudeau et al. 2007 |
| Collecting and archiving of DNA species | Vertebrates (mammals, birds, fish, reptiles), invertebrates | PCR, RLFP | DNA | Whole blood, tissues | FTA card | Smith and Burgoyn 2004 |
| DNA extraction optimisation for genetic studies | Elk, domestic dogs, Rocky Mountain bighorn sheep, mule deer | PCR | DNA | Whole blood | Nobuto filter paper strip, FTA card, FTA Elute card | Love Stowell et al. 2018 |
| Infection/causative agent/aim of the investigation | Living object | **Method** | Analyte | Dried sample | Sample carrier | Reference |
|-------------------------------------------------|---------------|------------|---------|--------------|----------------|-----------|
| Determination of avian sexing                    | Great Grey Shrike | PCR        | DNA     | Whole blood  | FTA card      | Gutiérrez-Corchero et al. 2002 |
| Seabirds                                         |               |            |         |              |                |           |
| Fighting cock, sun conure                        |               |            |         |              |                |           |
| Stork hybrids diagnostics                        | Stork         | PCR        | DNA     | Whole blood  | FTA card      | Yee et al. 2013 |
| Amphibians, crustaceans, fishes, molluscs, reptiles |               |            |         |              |                |           |
| Ranavirus infection (ranavirus)                  | Green frog    | PCR        | DNA     | Whole blood  | FTA card      | Forzán and Wood 2013 |
| Viral nervous necrosis (betanodavirus)           | Asian seabass | RT-PCR     | RNA     | Tissue homogenate, cell culture supernatant, gonadal fluid-milt and seawater spiked with betanodavirus | FTA card | Navaneeth Krishnan et al. 2016 |
| White spot disease (white spot syndrome virus)   | Shrimp        | PCR        | DNA     | Haemolymph   | FTA card      | Sudhakaran et al. 2009 |
| Yellow head virus infection (YH virus)           | Shrimp        | RT-PCR     | RNA     | Haemolymph   | ISOCODE filter paper, Schleider & Schuel | Kiatpathomchai et al. 2004 |
| Other investigations                              |               |            |         |              |                |           |
| Microsatellite and RFLP genotyping               | Northern pike, brown trout | PCR–RFLP  | DNA     | Body mucus, buccal cells smears | FTA card | Lucentini et al. 2006 |
| Microsatellite genotyping and mitochondrial sequencing | Abalon   | PCR, sequencing | DNA | Squash tissue samples (foot, epipodial tentacles, whole juveniles) | FTA card | Carr and Appleyard 2008 |
| Population genetic studies                       | Manta ray     | PCR        | DNA     | Mucus        | FTA Elute card | Kashiwagi et al. 2015 |
| Assessment of the vitamin D3 status (nutritional metabolic bone disease, NMBD) in captive animals | Oriental fire-bellied toad | Analysis (LC–MS/MS) was done by City Assays (UK) | 25-Hydroxyvitamin D3 | Whole blood | Test blotting strips | Michaels et al. 2015 |
| Assessment of wild-type diet composition and examination of fatty acid status for wild and managed care animals | Turtle | Analysis (GC) was done by Lipid Technologies, LLC (USA) | Fatty acids | Whole blood | PerkinElmer 226 spot saver RUO card | Dass et al. 2020; Koutsos et al. 2021 |
| Part of an annual continuing health assessment | San Cristóbal Galápagos tortoise | AAS, GC-C-IRMS | Mercury, stable carbon isotope fingerprinting of essential amino acids | Whole blood | Whatman 903 filter paper | Barst et al. 2020 |
| Assessing of mercury exposure and dietary carbon sources | Arctic char | AAS, GC-C-IRMS |          |              |                |           |
Table 1 continued

| *Infection/cause** | Living object | Sample carrier | Analyte | Method | Reference |
|---------------------|---------------|----------------|---------|--------|-----------|
| **Trophic position** | Arctic char   | Whatman 903 filter paper | Protein | FIA | Barst et al. 2021 |
| **Insects** | Insects | Whole blood | DNA | PCR | Snowden et al. 2002 |
| Thelohania solenopsae (micro- | Fire ant (Solenopsis invicta) | Whatman no.1 filter paper | DNA | PCR | Snowden et al. 2002 |
| Trypanosoma cruzi | Triatomine (Triatoma protracta) | Filter paper | DNA | PCR | Snowden et al. 2002 |
| Trypanosoma rangeli | Triatomine (Dipterocentron maximus) | Filter paper | DNA | PCR | Snowden et al. 2002 |
| Trypanosoma rangeli | Trypanosoma rangeli | Trypanosoma rangeli | DNA | PCR | Snowden et al. 2002 |
| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
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| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
| | Trypanosoma rangeli | | | PCR | Snowden et al. 2002 |
| | Trypano...
| Other investigations                                                                 | Living object               | **Method** | Analyte                        | Dried sample       | Sample carrier | Reference       |
|-------------------------------------------------------------------------------------|----------------------------|------------|--------------------------------|--------------------|----------------|-----------------|
| Insects identification (forensic applications)                                       | Calliphorids               | PCR        | DNA                            | Insect homogenate  | FTA card       | Harvey 2005     |
| Sample preservation and storage (insects and pathogen DNA)                          | House fly                  | PCR        | DNA                            | Nucleic acid extract | Qualitative filter paper | Owens and Szalanski 2005 |
| Specimen collection and storage                                                      | Aphid specimens            | PCR, sequencing | DNA                          | The purified DNA or the solution of the cell lysis buffer | Filter Paper Qualitative P5 (Thermo Fisher Scientific), FTA card | Miller et al. 2013 |
| DNA extraction optimisation                                                          | Chicken mite (Dermatophous gollinae) | PCR        | DNA                            | Mite suspension     | FTA card       | Desloire et al. 2006 |
| Genotyping of T. cruzi (genetic polymorphism)                                        | Whirlyfe                   | LSPP-PCR   | DNA                            | Smashed insects     | FTA plant card | Dickey et al. 2012 |
| Population genetic studies                                                           | Triatome                   | AFLP technique | DNA                          | Fecal spots         | FTA card       | Brito et al. 2008 |
| Amplification of endo-β-1,4-glucanase gene                                           | Tsetse fly                 | PCR        | DNA                            | Insect crash        | FTA card       | Lall et al. 2010 |
| Taxonomic identification of vector blood meal                                       | Mosquito                   | PCR        | DNA                            | Blood meal specimens | FTA card       | Reeves et al. 2016 |
| **Blood meal identification**                                                        | Mosquito                   | ELISA      | Antibodies                      | Gut                 | Whatman filter paper | Fall et al. 2012 |
| **Blood meal identification (fed on human, sheep, rat, rabbit, dog and chicken blood)** | Mosquito                   | MALDI-TOF MS | MS spectra                   | Crushed abdomen    | Filter paper   | Niare et al. 2017 |

*AD virus—Aujeszky disease virus, ASF virus—African swine fever virus, BVD virus—bovine viral diarrhea virus, CAEV virus—caprine arthritis-encephalitis virus, CD virus—canine distemper virus, EEE virus—Eastern equine encephalomyelitis virus, FMD virus—foot-and-mouth disease virus, HIF-1—hypoxia inducible factor-1, PPAR—peroxisome proliferator-activated receptor, PRRS virus—porcine reproductive and respiratory syndrome virus, SARM—selective androgen receptor modulators, SLE virus—St. Louis encephalitis virus, SVD virus—swine vesicular disease virus, VS virus—vesicular stomatitis virus, WWE virus—Western equine encephalomyelitis virus, YH virus—yellow head virus

**AAS—atomic absorption spectrometry, AFLP—amplified fragment length polymorphism, AGID—agar gel immunodiffusion test, DAT—direct agglutination test, DIG-ELISA—the diffusion-in-gel enzyme-linked immunosorbent assay, EA-IRMS—elemental analysis—isotope ratio mass spectrometry, ESI-MS/MS—electrospray tandem mass spectrometry, GC-C-IRMS—gas chromatography-combustion-isotope ratio mass spectrometry, GC-EC—gas chromatography with electron capture detection, GC-MS/MS—gas chromatography tandem quadrupole mass spectrometry, HA—hemagglutination, HI—haemagglutination inhibition, HPLC-ESI-MS/MS—high pressure liquid chromatography hyphenated to positive electrospray tandem mass spectrometry, HRGC-HRMS—high resolution gas chromatography-mass spectrometry, IC-MS—inductively coupled plasma mass spectrometry, ICT—immunochromatographic test (lateral flow immunoassay), IFA—indirect fluorescent antibody, KDRT—Kalazar detect rapid test, LC-ESI-MS/MS—liquid chromatography electrospray ionization mass spectrometry, LC-MS/MS—liquid chromatography-tandem mass spectrometry, LSPP-PCR—the low-stringency single specific primer—polymerase chain reaction, MALDI-TOF MS—matrix-assisted laser desorption/ionization time-of-flight mass spectrometry, MAI—modified agglutination test, MS/MS—tandem mass spectrometry, NAB—nuclear acid-based amplification, NGS—next generation sequencing metagenomics analysis, PCR-EIA—polymerase chain reaction-enzyme immunoassay, PCR-RFLP—nested polymerase chain reaction – restriction fragment length polymorphism, PCR-SSCP—a polymerase chain reaction and single-strand conformation polymorphism determination, PFIA—polarization fluorescence immunoassay, PrNT—a plaque reduction neutralization test, RFLP—restriction fragment length polymorphism or nucleotide sequencing, RT-LAMP—real-time reverse transcription-loop-mediated isothermal amplification assay, RT-PCR—reverse transcription—polymerase chain reaction, SNP—a single nucleotide polymorphism, SPGA-EDTA buffer—a Sucrose-Phosphate-Glutamate-Albumin buffer containing ethylenediaminetetraacetate, STR-PCR—short tandem repeat polymerase chain reaction, QAGP—quantitative agar gel precipitation, qRT-PCR—quantitative reverse transcription—polymerase chain reaction, UHPLC-MS/MS—ultra-high-performance liquid chromatography-tandem mass spectrometry, WGA—whole genome amplification
usual way of biofluids or homogenate/suspensions sampling onto filter material is a dropwise application. A part of absorbing material, for instance, in a form of strip, was also used for biofluids saturation (Table 1). Tissues and similar specimens are usually applied on a carrier in a form of smears or crushes. Insect saliva or dry fecal spots are collected by a direct exposure of insects onto a filter paper. Nevertheless, whole blood as a source of specific antibodies or genetic material remains the most commonly used biofluid among all dried samples taken from animals so far (Table 1). At the same time, it should be noted that due to a big diversity of animal species and the tasks of particular investigation, the variety of described dried biosamples is much wider than in human medicine, where body fluids are usually utilized. Type of the used specimen is determined by the peculiarities of causaruve agent localisation in a body, for example, avian influenza virus can be found in parts of bird’s body but not in blood, rabies virus – in brain tissue, infectious bursal disease virus – in bursa, etc. (Tables 1 and 2).

**Carriers for dried samples and sample pretreatment**

Pure cellulose as an affordable and established material for DBS sampling has been rooted from neonatal screening starting from the 1960-s, and since then it was considered to be the standard sample carrier in most medical and scientific works (Demirev 2013; Meesters and Hooff 2013; Sharma et al. 2014). This type of membrane material was used in the majority of the reported veterinary and biological investigations too (Table 1). The investigations were carried out with cellulose absorbing filter paper (manufactured from 100% pure cotton) of various trademarks: mainly it was widespread Whatman (no.1, no.3, no.4, 3MM filter paper and others), less frequent it was Munktell, Schleicher&Schuell and some others, as well as blotting paper (Table 1). Some researchers used an ordinary filter paper or cone type paper typically used for coffee filters (Quintana et al. 2009) and even plain office and stationery paper (Maw et al. 2006; Suriyaphol et al. 2014) for drying and further it was used for PCR amplification of genetic material. Generally speaking, any porous cellulose or other absorbing material is sufficient to saturate whole blood or other biological fluids/specimens, and it allows to analyse the absorbed biomaterial at least qualitatively. The sampling method onto common papers can be suitable for surveys where laboratory resources are limited (Maw et al. 2006), but this type of material’s applicability for the particular investigation should be evaluated (Suriyaphol et al. 2014). Commercial chemically treated cellulose-based sampling cards, such as protein saver card 903, FTA card, FTA elute card (Whatman) were used for sampling quite often (Table 1). Special FTA (Flinders Technology Association) cards were developed to proceed cell lysis and protein denaturation while the biosample was applied onto the material and to preserve nucleic acids for subsequent DNA or RNA analysis. In case of PCR, FTA cards impregnated with detergents and other special substances are the most frequently used cards (Table 1). Moreover, they can provide virus inactivation, and are the safest to use among other Whatman filter papers (Wannaratana et al. 2021). Wannaratana et al. (2021) found that three Whatman cellulose carriers, namely FTA card, 903 card and qualitative filter paper grade 2 can preserve Marek’s disease virus DNA for at least 30 days post post but only on FTA cards no viable Newcastle disease virus was detected at all post spotted timepoints. For specific purposes, a common laboratory filter paper or stationary paper can be considered as affordable cost-efficient absorbing material in comparison with more expensive commercially available special sampling cards. For example, seeking for safe, inexpensive, simple and easy method of sample preparations, Maw et al. (2006) showed that ordinary paper with phenol fixation inactivates and sustains infectious bursal disease virus RNA as the FTA card. So, regardless of the paper quality, storage period and fixation method, viral RNA was consistently detected in all bursa dried imprints after 30 days storage at 37 °C. Under determination of avian sexing in DBS Suriyaphol et al. (2014) concluded that the most practical and cost-effective method across different types of commercial sampling cards, ordinary filter and stationery paper was the utilisation of Whatman grade 1 filter paper (ordinary filter paper) with the combination of methanol fixation and boiling.

It is well known that cellulose material used for whole blood absorption has some week points, such as haematocrit effect and chromatographic effect, which are generally affecting the low molecular weight substances analysis and quantitative analysis (Velghe et al. 2019). These effects resulted from rheological properties of whole blood, hematocrit varying from sample to sample, and from the nature of cellulose material with hollow fibres, all together these factors influence the assay accuracy (De Kesel et al. 2013). That is why, along with other numerous approaches and devices for volumetric sampling of whole blood, the researchers consider the alternative non-cellulose materials for DBS preparations to minimize these effects. Some veterinary studies were performed with the use of nitrocellulose, nylon (Vilček et al. 2001; Wang et al. 2002) and fiberglass membranes (Samsonova et al. 2014, 2017, 2019a, b; Saushkin et al. 2016a, b, 2019). Just a few works were devoted to compare cellulose and non-cellulose membrane carriers for particular investigations. Vilček et al. (2001) compared cellulose, nitrocellulose and nylon carriers under the storage of dried whole blood and serum containing bovine viral diarrhea virus (RNA virus); the lowest yield of PCR products was obtained for classical
fritration paper. DBS stored on different carriers at +4 °C or -20 °C (up to 4 weeks) and at room temperature (up to 6 months) were stable. Wang et al. (2002) also compared cellulose, nitrocellulose and nylon carriers upon detection of duck hepatitis B virus in dried serum, and found that cellulose paper provides the highest yield of PCR products and nylon membrane provides the lowest.

All Whatman and similar cards are manufactured as a small piece of thick cellulose filter paper with special circled zones for a sample application. As reported, animal DMS were also collected with the help of some alternative sampling devices such as Tego Card (Yoon et al. 2010; Sun et al. 2013), Hemaspot device (Rosypal et al. 2014), isoCode stix (Jefferies et al. 2007) and Nobuto cellulose strips (Table 1). Nobuto cellulose stripes were first used in 1966 by Japanese scientists Kenzo Nobuto to collect swine blood for serodiagnosis of toxoplasmosis (Nobuto 1966). The strips consisted of two parts: the absorbent area and the distribution area. Later, Nobuto cellulose strips were found useful for wildlife sampling as a convenient tool for whole blood collection in a field, directly from a puncture or a wound (Table 1). Another type of strips made of fiberglass and divided into equal zones for collecting and analysing of dried whole blood, serum or milk by ELISA and PCR were described (Samsonova et al. 2014, 2017, 2019a, b; Saushkin et al. 2016a, b, 2019). The proposed strip provides volumetric biofluid microsampling due to the properties of absorbing non-cellulose material consisted from solid fibers and the shape of the strip. This fiber glass strip has advantages over cellulose material in terms of mechanical strength, easiness of aliquoting of dried sample, small influence of sample hematocrit and uniform biofluid/analyte distribution across the strip (Samsonova et al. 2016, 2017, 2022; Saushkin et al. 2019). Based on similar principle a comb-shape 12-spot DBS card was designed that can be directly placed into ELISA plate wells for elution of antibodies (Knutttila et al. 2014). Moreover, a domestic device that can introduce eight blood combs simultaneously to the ELISA plate with no need for a separate elution/dilution step and speeding up the sample pretreatment was used. Overall, it should be highlighted that a strip of absorbing material can be considered as the most convenient way of whole blood sampling in the field so far, especially in hush conditions, with no need of dosing equipment. It is significant that in some works, the researchers, for the convenience of applying the blood sample, cut the cellulose material into strips for the possibility of impregnation of the membrane directly from puncture and ease of dosing in the subsequent stages (Aldo Gaggero and Sutmöller 1965; Lana et al. 1983; Avakian and Dick 1985; Roy et al. 1994, 1992; Stallknecht and Davidson 1992; Nogami et al. 1992; Reisen et al. 1994; Thangavelu et al. 2000; Dubay et al. 2006; Jefferies et al. 2007; de Oliveira et al. 2011; Randriampanarany et al. 2014).

Analysis of the published works revealed that to perform serological tests the conditions of dried biosample extraction from cellulose carrier were chosen by authors empirically and usually included incubation of dried sample in a buffer solution from 1–2 h to overnight or even 24 h at room temperature or +4 °C. At the same time it was shown that 20–30 incubation under shaking at room temperature is enough to release antibodies from whole blood, serum or plasma dried on a glassfibre strip (Saushkin et al. 2016b, a, 2019; Samsonova et al. 2019a, b). Some works described the optimization of antibodies elution time and temperature (Hopkins et al. 1998; Chadio et al. 2002). Similarly, to increase concentration of cattle pregnancy-associated glycoproteins (PAGs) in paper eluate Sun et al. (2013) used a modified ELISA protocol including increased sample volume, longer incubation time and plate shaking during incubation. In general, there are no established standardized procedures for antibodies extraction from dried biological fluids. Antibodies have been extracted from a membrane carrier into different buffers such as borate buffer (Wolff and Hudson 1974; Sacks et al. 2002; Chomel et al. 2004; Bevins et al. 2016; Chandler et al. 2018), Tris buffer (Nogami et al. 1992; Chandler et al. 2018), physiological saline (Wolff and Hudson 1974; Kalayou et al. 2011), phosphate buffered saline (PBS) with detergent (Afshar et al. 1987, 1992; Roy et al. 1992; Hopkins et al. 1998; Holland et al. 2002; de Oliveira et al. 2011; Dam-Tuxen et al. 2014; Andersson et al. 2015; Al-Kappany et al. 2018) or PBS with no detergent (Aldo Gaggero and Sutmöller 1965; Platt and Adams 1976; Armstrong et al. 1991; Stallknecht and Davidson 1992; Cabrera et al. 1999; Mueller-Anneling et al. 2000; da Silva et al. 2000; Holland et al. 2002; Jordan et al. 2005; Dalerum et al. 2005; Mucker et al. 2006; Yoon et al. 2010; Dusek et al. 2011; Mercier et al. 2013; Rosypal et al. 2014; Abbott et al. 2014; Aston et al. 2014; Kamps et al. 2015; O’Hara et al. 2018; Santos et al. 2018; Ytrehus et al. 2021; Jennings-Gaines et al. 2021). Usually, the amount of blood absorbed and then retained from a filter paper was not assessed; however, that is an important issue during assay development or commercial ELISA kit adaptation for dried samples. Yu et al. (2007) established a linear equation between dry weight of filter paper and known volume of absorbed whole blood to estimate Sika deer blood volume absorbed by filter discs taken in the field. Aston et al. (2014) performed retrospective evaluation of several kinds of laboratory-grade filter paper along with commercial cellulose Whatman cards during anti-T. gondii antibody elution and detection from DBS taken from hunted ungulates. The dried blood concentration across different filter papers was determined by means of pipetting a predetermined volume of blood and calculating the area of the blood spot. To calculate dilution factor the authors modified agglutination assay protocol taking into account the number of punched disks (from blood spot) and
| Antibodies | Analyte | *Dried sample spots or imprints | Carrier | **Maximum time of storage and storage conditions | Reference |
|------------|--------|-------------------------------|--------|-----------------------------------------------|-----------|
| Antibodies (avian influenza virus) | Antibodies | Whole blood | Nobuto filter paper strip | 3 months at RT | Dusek et al. 2011 |
| Antibodies (Avian influenza virus) | Antibodies | Whole blood | Whatman no.1 filter paper | 1 year at 4 °C | Banks 1985 |
| Antibodies (bovine herpesvirus-1) | Antibodies | Whole blood, serum | Whatman no.3 filter paper | 8 months at 4 °C | de Oliveira et al. 2011 |
| Antibodies (bovine leucosis) | Antibodies | Whole blood | Fiberglass strip | 7 days at 37 °C; 24 h at 60 °C | Saushkin et al. 2019 |
| Antibodies (foot-and-mouth disease) | Antibodies | Whole blood, serum | Blotting paper | 60 days at RT | Aldo Gaggero and Sutmöller 1965 |
| Antibodies (Newcastle disease) | Antibodies | Whole blood | Whatman no.1 filter paper | 3 weeks at RT | Roy et al. 1992 |
| Antibodies (plague (Y. pestis)) | Antibodies | Whole blood | Nobuto filter paper strip | 454 days at -20 °C and 4 °C | Bevins et al. 2016 |
| Antibodies (toxoplasmosis) | Antibodies | Whole blood | Quantitative filter paper strips (Toyo Roshi Kaisha) | Up to 12 months (-80 °C to RT) with silica gel | Nogami et al. 1992 |
| Antibodies (vesicular stomatitis) | Antibodies | Serum | Blotting paper | 7 days at 37 °C; 1 day at 56 °C | Adams and Hanson 1956 |
| Antibodies (visceral leishmaniasis) | Antibodies | Plasma | HemaSpot device | 1 month at RT; 79% drop in 6 months at RT | Rosypal et al. 2014 |
| Antibodies (brucellosis, neosporosis, West Nile virus disease, herpes, bovine parainfluenza, bovine respiratory disease; bovine viral diarrhea) | Antibodies | Whole blood | Nobuto filter paper strip | Up to 2 years at RT | Curry et al. 2014b |
| Antibodies (infectious bursal disease, infectious bronchitis, mycoplasmosis) | Antibodies | Whole blood, serum | Fiberglass strip | 7 days at 4 °C (serum); 7 days at 4 °C, RT, 37 °C; 60 days at 60 °C (blood) | Samsonova et al. 2019a |
| RNA/DNA (infectious agents) | RNA/DNA | Whole blood | FTA card | 10 months under field conditions | Uttenthal et al. 2013 |
| Viruses | Viruses | Whole blood | Whatman 3MM filter paper | 9 months at RT | Randriamparany et al. 2014 |
| African swine fever virus (DNA) | Viruses | Swab samples | FTA card | 5 months at RT | Abdelwhab et al. 2011 |
| Avian influenza virus (RNA) | Viruses | Cloacal and oropharyngeal swabs | FTA card | Up to 30 days at RT for most subtypes | Keeler et al. 2012 |
| Bovine herpesvirus-1 (DNA) | Viruses | Bovine semen | FTA card | 28 days at 4–37 °C | Sarangi et al. 2018 |
**Table 2** (continued)

| Analyte                              | *Dried sample spots or imprints | Carrier                                          | **Maximum time of storage and storage conditions | Reference                           |
|--------------------------------------|---------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------|
| **Bovine leukaemia virus (DNA)**     | Whole blood                     | Fiberglass strip                                 | 7 days at 37 °C; 24 h at 60 °C                   | Saushkin et al. 2019                 |
| Bovine respiratory disease complex   | Diagnostic swab fluids, deep nasal swabs | Filter paper (Toyo Roshi Kaisha)                  | At least 10 days at RT                           | El Daous et al. 2020                |
| (bovine viral diarrheal virus (RNA), bovine respiratory syncytial virus (RNA), bovine coronavirus (RNA), bovine herpesvirus-1 (DNA)) |                                  | FTA card                                         | Up to 14 days at -27 °C to 46 °C          | Liang et al. 2014                   |
| **Bovine viral diarrheal virus (RNA)** | Whole blood, serum              | Whatman no.1 filter paper, nitrocellulose no.71002, HYBOND-M nylon | Up to 4 weeks at -20 °C, 4 °C and RT; 6 months at RT | Vilček et al. 2001                 |
| **Duck hepatitis B virus (DNA)**     | Serum                           | Whatman no.1 filter paper                        | 4 weeks at -70 °C and -20 °C; decreased yield at temp. more than 4 °C | Wang et al. 2002                     |
| **Foot-and-mouth disease virus**     | Cell culture isolates, tongue epithelium | FTA card                                         | 80–120 days                                     | Muthukrishnan et al. 2008           |
| (RNA)                                | Cell culture isolates, tongue and foot epithelium |                                    | 22–56 days at 21–45 °C and relative humidity 20–100% | Madhanmohan et al. 2016             |
|                                      | Cell culture isolates, tongue epithelial suspension and impression smears |                                    | Up to 6 weeks at 4–37 °C                      | Biswal et al. 2016                  |
| **Fowl adenovirus I (DNA)**          | Liver                           | FTA card                                         | 198 days at -20 °C                              | Moscoso et al. 2007                 |
| **Infectious bronchitis virus (RNA)** | Tracheal swabs                  | FTA card                                         | Up to 15 days at 4 °C and RT, slight decrease at 41 °C | Moscoso et al. 2005                 |
|                                      | Tissues and swab samples        | FTA card                                         | Up to 21 days at up to 40 °C (partial sequencing); Up to 14 days at 4 °C and RT (full sequencing) | Manswr et al. 2018                  |
| **Infectious bursal disease virus**  | Water solution, spleen smears (HEV) | Hybond C nitrocellulose filter paper             | 5–30 days at RT or 37 °C                       | Pitcovski et al. 1999               |
| (RNA)                                | Bursa                           | FTA card                                         | 15 days at RT, 8 months at -20 °C; 1–3 months at 25 °C and at least 8 months at -20 °C for RFLP or sequencing | Moscoso et al. 2006                 |
| **Hemorrhagic enteritis virus (DNA)** |                                 | Chromatography paper, filter paper, stationery copy paper, FTA card | 30 days at 37 °C                               | Maw et al. 2006                     |
| **Infectious bursal disease virus**  | Blood, solid tumors             | FTA card                                         | 8 months at RT                                  | Cortes et al. 2009                  |
| (RNA)                                | Vaccine                         | FTA card, 903 card, qualitative filter paper grade 2 (all Whatman) | Up to 30 days at RT                            | Wannaratana et al. 2021             |
Table 2 (continued)

| Analyte                                      | *Dried sample spots or imprints                                      | Carrier                      | **Maximum time of storage and storage conditions                        | Reference                        |
|----------------------------------------------|---------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------|----------------------------------|
| Metapneumovirus (RNA)                        | Turbinate, trachea and lung                                         | FTA card                     | Up to 60 days at 4 to 6 °C                                               | Awad et al. 2014                 |
| Newcastle disease virus (RNA)                | Trachea, lung, caecal tonsil and cloacal faeces                     | FTA card                     | 15 days at RT                                                            | Perozo et al. 2006               |
|                                             | Caecal tonsils, kidney, proventriculus, spleen, trachea, faecal swabs and intestinal lesions | FTA card                     | Up to 30 days at 4 °C and RT                                             | Narayanan et al. 2010            |
| Peste des petits ruminants virus (RNA)       | Whole blood                                                         | Whatman 3MM filter paper, FTA | 3 months at up to 32 °C (RNA); 9 months at up to 37 °C (DNA)             | Michaud et al. 2007              |
| African swine fever virus (DNA)              | Whole blood, nasal swabs                                            | Whatman 3MM filter paper, FTA | 16 months at -70 °C; 7 days at RT (molecular detection and genotyping)   | Bhuiyan et al. 2014              |
| Peste des petits ruminants virus (RNA)       | Whole blood                                                         | Whole blood, serum, organs (lung, tonsil, and superficial inguinal lymph nodes), oral fluid | FTA card | 14 days at 4 °C and RT                                                  | Linhares et al. 2012              |
| Porcine reproductive and respiratory syndrome virus (RNA) | Whole blood, serum, organs (lung, tonsil, and superficial inguinal lymph nodes), oral fluid | FTA card | 14 days at 4 °C and RT | Linhares et al. 2012 |
| Swine influenza virus (RNA)                  | Allantoic fluid, nasal swabs, lung tissue                           | FTA card                     | 7 days at RT                                                             | Maldonado et al. 2009            |
| Rabies virus (RNA)                           | Brain tissue                                                       | no. 903 filter paper; Schleicher and Schuell | 222 days at RT                                                                   | Wacharapluesadee et al. 2003     |
|                                             | Virus isolates                                                     | FTA card                     | 35 days at RT                                                            | Picard-Meyer et al. 2007         |
|                                             | Brain tissue                                                       | FTA card                     | 3 months at -80 °C and -20 °C; degradation of sRNA at 4 °C and RT storage | Sakai et al. 2015                |
| Ross River virus (RNA)                       | Brain tissue                                                       | Whatman 903 filter paper     | Up to 2 years at RT                                                      | Rasolonjatovo et al. 2020        |
| Fish betanodavirus (RNA)                     | Mosquito saliva                                                    | Honey-soaked FTA card, filter paper | 28 days at RT                                                                  | Hall-Mendelin et al. 2010        |
| Other infectious agents (DNA)                | Tissue homogenate, cell culture supernatant, gonadal fluid-milt and seawater spiked with betanodavirus | FTA card                     | 28 days at 4 °C                                                           | Navaneeth Krishnan et al. 2016   |
| Babesia gibsoni (DNA)                        | Whole blood                                                        | Whatman 3MM filter paper     | 2 months at RT                                                           | Tani et al. 2008                 |
| Micoplasma (M. gallicum and M. synoviae) (DNA) | Tracheal swabs                                                     | FTA card                     | 60 days at 4–40 °C                                                       | Moscoso et al. 2004              |
| Trypanosoma species (DNA)                    | Buffy coat                                                         | Whatman no.3 filter paper    | 5 months at RT; 2 years at -20 °C (results not shown)                     | Geyesen et al. 2003              |
| Streptococcus agalactiae (DNA)               | Milk                                                               | Xinhua grade 3 chr paper treated with EDTA | Up to 4 weeks at RT and 37 °C                                             | Wu et al. 2008                   |
Table 2 (continued)

| Analyte                                                                 | *Dried sample spots or imprints | Carrier                                                                 | **Maximum time of storage and storage conditions | Reference          |
|------------------------------------------------------------------------|---------------------------------|------------------------------------------------------------------------|--------------------------------------------------|--------------------|
| **Other DNA investigations**                                           |                                 |                                                                        |                                                  |                    |
| Aphid specimens collection and storage (DNA)                          |                                 | Filter Paper Qualitative P5 (Thermo Fisher Scientific), FTA card       | Up to 2 years                                    | Miller et al. 2013 |
| Avian DNA                                                              | Whole blood                     | FTA card                                                               | Up to 4 years                                    | Smith and Burgoyne 2004 |
| Chicken mites (*Dermanyssus gallinae*) (DNA)                          | Mite homogenate                 | FTA card                                                               | 1 year at RT                                     | Desloire et al. 2006 |
| Genotyping of casein A1/A2 variants (DNA)                              | Milk                             | Whatman no. 3 filter paper treated with SPGA-EDTA buffer               | Up to 1 month at 80 °C, -20 °C, RT               | Venkatesh and Gopal 2018 |
| Porcine DNA                                                            | Whole blood                     | FTA card                                                               | Up to 3 years                                    | Fowler et al. 2012  |
| **Other substances**                                                   |                                 |                                                                        |                                                  |                    |
| Cyclosporin A                                                          | Whole blood                     | Whatman 903 card                                                       | 9 days at RT in the dark under a dry atmosphere  | Mohamed et al. 2012 |
| Enrofloxacin, ciprofloxacin                                           | Whole blood                     | Filter paper                                                           | 4 weeks at -20 °C, 4 °C and RT                   | Posyniak et al. 2002 |
| Fatty acids                                                            | Whole blood                     | PerkinElmer spot saver card                                             | 1 year at -80 °C                                 | Wood et al. 2011c   |
| Pregnancy-associated glycoproteins (PAGs)                              | Whole blood                     | TEGO card                                                              | 14 days at 4 °C; 22–34% reduction upon storage at RT (14 days) | Sun et al. 2013     |
| Progesterone                                                           | Whole blood                     | Schleicher and Schuell 2992 filter paper                               | Several weeks at -20 °C, RT and 4 °C; Up to 30% drop after 3 months | Chadio et al. 2002  |
|                                                                      | Milk                            | Fiberglass strip                                                       | 1 month at 4 °C; 7 days at 37 °C; 24 h at 60 °C | Samsonova et al. 2014, 2017 |
| Lysosomal enzymes                                                     | Whole blood                     | Munktell TFN 06–079 card                                               | 6 months at 4 °C; 20% reduction of enzyme activity in 1 year storage at RT (except β-glucuronidase) | Sewell et al. 2012  |
| Mercury                                                               | Whole blood                     | Whatman 903 card                                                       | Up to 1 year at -20 °C to RT; 20 min at 100 °C; Up to 180 min at 56 °C; 3 months at RT to 30 °C up to 80% humidity | Perkins and Basu 2018 |
| Toxic heavy metals (As, Se, Hg, Pb)                                    | Whole blood                     | Whatman 903 card                                                       | 24 months at -20 °C                             | Lehner et al. 2013  |
| 50 compounds including anabolic steroids, β2-adrenoceptor agonists, corticosteroids, HIF-1 stabilizers, PPAR δ agonists, SARMs, and aromatase inhibitors | Whole blood                     | Whatman 903 card                                                       | 87 days at RT and 30–60% humidity The majority of substances showed good stability (> 50% of initial concentration) | Moeller and Yang 2021 |

*HEV—hemorrhagic enteritis virus, HIF-1—hypoxia inducible factor-1, PPAR—peroxisome proliferator-activated receptor, SARM—selective androgen receptor modulators

**RT – room temperature
the elution buffer volume. This method allows researchers to adapt their approaches to different available absorbing materials. Fiber glass material in a form of a strip allows the calculating of predetermined sorption capacity per a single square piece of a strip, so the development and assessment of the target analyte extraction efficiency is an easier task than for cellulose material (Samsonova et al. 2016, 2017, 2019b; Saushkin et al. 2019).

Nucleic acids extraction from DMS was performed with the use of most common DNA/RNA extraction methods. For example, Cardona-Ospina et al. (2019) summarized RNA extraction from FTA cards used for detection and characterization of viral RNA pathogens from fieldwork. Commercially available DNA extraction kits can be optimized to provide the most accurate and precise recovery for molecular epidemiological studies as it was shown for Trypanosoma cruzi DNA extracted from canine and skunk DBS (Gulas-Wroblewski et al. 2021). The issue of the best practice for preparation of samples from FTA cards for the molecular diagnosis under large-scale epidemiological studies was addressed in the work of Ahmed et al. (2011) using African trypanosomes as a model object. The authors found that to improve the detection of trypanosomes by PCR, DBS should better be eluted from cards using Chelex®100 than directly applied into PCR. The authors also emphasized that to overcome any problems associated with uneven distribution of parasite DNA on the card matrix and to increase the sensitivity of the molecular diagnosis of trypanosome infections the increased numbers of discs cut from DBS should be used. Seeking for the most effective high-quality unfragmented DNA extraction method for genomic studies Love Stowell et al. (2018) compared three types of paper (Nobuto filter paper strip, FTA card, FTA Elute card) and four commonly used extraction methods with some modifications using ungulate and canine dried whole blood. The authors concluded that preservation FTA cards were not adequate for providing unfragmented DNA for downstream genomic applications such as microsatellite and genomic sequencing especially for mammals which have non-nucleated blood cells. However, other researches successfully used FTA cards for genetic applications such as microsatellite genotyping (King et al. 2005; Lucentini et al. 2006; Carr and Appleyard 2008; Heim et al. 2012; Nunziata et al. 2016). For example, Lucentini et al. (2006) described a nondestructive method for obtaining the high-quality DNA from fish body mucus and buccal cells, making it the best choice for populational genotyping. In another investigation FTA cards was shown to be a good source of high-quality abalone DNA particularly for mitochondrial DNA and nuclear microsatellite amplifications for abalone (Carr and Appleyard 2008).

The separation of a part of the dried biospecimen spot on a membrane is usually carried out using a puncher, obtaining one or multiple paper disks of small diameter. Using of a puncher for DNA/RNA samples can be associated with cross contamination, which demands additional cleaning step and blank cards punching (Linhares et al. 2012). At the same time, the use of non-cleaned and cleaned scissors showed no false positive results, and provided correct amplicon sizes (Suriyaphol et al. 2014). It was also reported, that the standard protocol of punching a membrane disk with dried blood sample leads to strong cross-contamination, despite cleaning the puncher with alcohol and using sterile wipes (Jefferies et al. 2007). The authors sequentially punched sterile filter paper, purified by alcohol after a positive sample; and obtained six potentially contaminated disks. Further, these disks were subjected to the standard procedure of DNA extraction and amplification; it showed that a false-positive result could be obtained even though the third-punched disk of sterile paper was used.

Extraction methods for other substances depended on the extractant type, thus enzymes and other proteins were usually extracted into buffers whereas for the low molecular substances organic solvents were preferably used. PAGs were extracted into PBS for 1 h at room temperature (Sun et al. 2013) and cholinesterase was extracted with the water solution of Triton X-100 (Trudeau et al. 2007). Progesterone was extracted from dried blood water eluate with the use of diethyl ether (Lin et al. 1988), from DBS—into PBS supplied with bovine serum albumin (Chadio et al. 2002), or alternatively it was released from dried milk during immunological reaction (Samsonova et al. 2014, 2017). To recover antibiotic enrofloxacin and its metabolite ciprofloxacin from dried blood Posyniak et al. (2002) found that among the investigated eluents the best one was acetonitrile. Moreover, the eluate ultrasonication showed preferences over shaking in terms of better extraction and protein denaturation. Acylcarnitines from dried serum spots were extracted with methanol (Sander et al. 2018; Worku et al. 2021).

To summarize it all, it should be emphasized that the choice and evaluation of a filter paper or a sampling card from a variety of available items is determined by a specific goal and optimal criteria for a particular task. An extraction procedure should be optimised to keep extractant level as high as possible, preferably close to that of the corresponding liquid sample, as it was shown for DNA/RNA extraction protocols from engorged and unfed individual mites (Desloire et al. 2006), from canine DBS (Tani et al. 2008) and from dried brain tissue (Sakai et al. 2015).

Methods and detected substances

Veterinary, biological and ecological investigations, based on DBS technology, are supported by a range of immunochemical, genetic and instrumental analytical methods. Veterinary diagnostics with the use of DMS are based on
the results of a variety of methods, including serological methods for the specific antibodies detection and PCR to reveal pathogen genetic material (Table 1). Serological methods for filter paper eluates include virus neutralization test, methods based on precipitation of antigen–antibody complex in agarose gel, indirect fluorescent antibody test, a variety of agglutination tests, radioimmunoassays, immunochromatographic test, and multiple variants of ELISA (Table 1). ELISA was also used to detect progesterone in cows’ dried milk and pigs’ dried blood (Lin et al. 1988; Chadio et al. 2002; Samsonova et al. 2014, 2017) and PAGs in cows’ dried blood (Sun et al. 2013) as pregnancy markers. A variety of PCR methods and its modifications used for DMS eluate amplification are vast, and included nested PCR, a hemi-nested PCR, real-time reverse transcription-loop-mediated isothermal amplification assay (RT-LAMP), the low-stringency single specific primer PCR (LSSP–PCR), and others (Table 1). Amplified fragment length polymorphism—AFLP, nested polymerase chain reaction – restriction fragment length polymorphism—PCR–RFLP, nucleic acid sequence-based amplification—NASBA, sequencing, DNA barcoding and other techniques were employed for identification and confirmation of disease causative agent, or investigations of gene polymorphism, genotyping, phylogenetic analysis and population genetic studies (Table 1).

Instrumental analytical methods, such as high performance liquid chromatography (HPLC), inductively coupled plasma mass spectrometry (ICP-MS), liquid chromatography (LC), mass-spectrometry (MS), atomic absorption spectrometry (AAS), and others were used for detection of pesticides and toxic environmental contaminants in wild birds (Shlosberg et al. 2011, 2012; Lehner et al. 2018), antibiotics in chickens (Posyniak et al. 2002), toxic heavy metals in wild birds and animals (Shlosberg et al. 2011, 2012; Lehner et al. 2013; Hansen et al. 2014; Perkins and Basu 2018; McHuron et al. 2019), cyclosporine A in cats (Mohamed et al. 2012) and doping agents in horses (Moeller and Yang 2021). Lysosomal enzyme activity in cats and dogs was estimated by fluorescent method (Sewell et al. 2012), cholinesterase activity as function of its inhibitors (as organophosphate and carbamate insecticides) in wild birds was performed by spectrophotometric method (Trudeau et al. 2007), blood meal identification in mosquitos was done by MS spectra (Niare et al. 2017).

**Dried veterinary samples storage stability**

Remote blood sampling for diagnostics and scientific investigations should be supported by the analytes stability in dried biological matrix, shipped from the farm/field to the laboratory and then stored until needed. In veterinary works, storage stability issue has been addressed in relation to the recovery of antibodies, nucleic acids and other substances across a variety of the DMS specimens (Table 2). Paper-immobilised antibodies usually showed good storage stability and temperature and humidity resistance probably due to their relatively rigid three-dimensional structures (Wang et al. 2012) and their quite high concentration and protein surroundings in dried blood. In veterinary diagnostics high storage stability of antibodies was described for dried whole blood, serum and plasma (Adams and Hanson 1956; Karstad et al. 1957; Benson and Mickle 1964; Aldo Gaggero and Sutmöller 1965; Stallknecht and Davidson 1992; Dubay et al. 2006; Curry et al. 2014a; Nemeth et al. 2017, 2021). Majority of the antibodies stability studies were performed on common filter paper and fiber glass stripes (Table 2). Curry et al. (2014b) showed good long-term antibodies stability (up to 2 years at ambient conditions) in reindeer and caribou DBS collected on Nobuto filter paper stripes in the field. Interestingly, better storage stability of chicken immunoglobulins stored on fiber glass strip was observed for dried whole blood than for dried serum samples (Samsonova et al. 2019a).

Many investigators examined viral and other causative agents storage stability (RNA or DNA) on sampling cards, mostly on nucleic acids preservation cards like FTA, or other absorbing materials (Table 2). Thus, Pitcovski et al. (1999) used two non-enveloped viruses, infectious bursal disease virus (IBDV, RNA virus) that infects chickens or hemorrhagic enteritis virus (HEV, DNA virus) that usually affects turkeys as model objects that were applied onto nitrocellulose membrane in a water solution or within spleen smears (HEV). It was shown that viruses could be stored in dried form on paper for 5–30 days at room temperature or 37 °C, so this method permits the storage of viral samples and shipping them from the field to a laboratory. Viral RNA was found to remain stable in dried samples for different avian viruses such as Newcastle disease virus (Perozo et al. 2006; Narayanan et al. 2010), infectious bronchitis virus (Moscoco et al. 2005; Manswr et al. 2018), infectious bursal disease virus (Moscoso et al. 2006; Maw et al. 2006), avian influenza virus (Abdelwhab et al. 2011; Keeler et al. 2012; Jóźwiak et al. 2016) and avian metapneumovirus (aMPV) (Awad et al. 2014). It was possible to perform molecular characterization of both subtypes A and B aMPV, with the use of inoculated FTA cards stored for up to 60 days at 4 °C to 6 °C (Awad et al. 2014). Among livestock RNA viruses investigated included rabies virus (Wucharapraesadee et al. 2003; Picard-Meyer et al. 2007; Sakai et al. 2015; Rasolonjato et al. 2020), foot-and-mouth disease virus (FMDV) (Muthukrishnan et al. 2008; Biswal et al. 2016; Madhanmohan et al. 2016), Peste des petits ruminants virus (PPRV) (Michaud et al. 2007; Bhuiyan et al. 2014), porcine reproductive and respiratory syndrome virus (Linhares et al. 2012), Ross river virus (RRV) (Hall-Mendelin et al. 2010),
swine influenza virus (Maldonado et al. 2009), bovine viral diarrhea virus (Vilček et al. 2001; Liang et al. 2014), bovine respiratory syncytial virus and bovine coronavirus (Liang et al. 2014). Thus, rabies virus was confirmed to be stable within dried brain tissue stored on filter paper up to 2 years at room temperature (Wacharapluesadee et al. 2003; Rasonjatovo et al. 2020). However, Sakai et al. (2015) reported degradation of viral RNAs, which occurred after storage of dried brain tissue on FTA card at 4 °C and room temperature, whereas viral RNA was stable over 3 months on the cards stored at −80 °C or −20 °C. It seems that nucleic acid preservation cards impregnated with special lysing and denaturing substances (FTA cards) were not the best choice for long-term storage of rabies virus. Bhuiyan et al. (2014) revealed PPRV virus successful storage on filter paper at -70 °C for 16 months and at RT for 7 days to perform molecular detection and genotyping. Hall-Mendelin et al. (2010) reported that both honey-soaked FTA cards and untreated filter paper cards were able to bind RRV RNA from mosquito saliva and preserve it at 23 °C for at least 28 days. Natarajan et al. (2000) demonstrated the usefulness of FTA cards for the preservation of mammalian and plant specimens for subsequent RNA analysis. Summarising literature data of the reported effectiveness of FTA cards for storage and shipment of viral RNA, Cardona-Ospina et al. (2019) concluded that the cards could be a suitable option for these purposes in areas where proper conditions for RNA preservation are difficult to achieve. Different DNA viruses usually demonstrated good storage stability in dried samples, for example, avian Marek’s disease virus (Cortes et al. 2009), duck hepatitis B virus (Wang et al. 2002) and fowl adenovirus I (Moscoso et al. 2007), bovine herpesvirus-1 (Sarangi et al. 2018) and bovine leucosis virus (Saushkin et al. 2019; El Daous et al. 2020), African swine fever virus (Michaud et al. 2007; Uttenthal et al. 2013; Randriamparany et al. 2014). Common filter papers are cheap and could be as good as more expensive commercial FTA cards for virus storage, like it was shown for African swine fever virus (Uttenthal et al. 2013; Randriamparany et al. 2014), infectious bursal disease virus (Moscoso et al. 2006; Maw et al. 2006) and Marek’s disease virus (Cortes et al. 2009; Wannaratana et al. 2021). In another investigation, FTA cards and Whatmann 3MM filter paper (cheaper option) showed similar results for DBS long-term storage (up to 9 months) at ambient and tropical temperature (22, 32 and 37 oC) to detect RNA and DNA containing viruses (Michaud et al. 2007).

DNA of other causative agents such as Mycoplasma (Moscoso et al. 2004), B. gibsoni, a protozoan parasite (Tani et al. 2008), Trypanosoma, unciliated parasitic flagellate protozoa (Gysen et al. 2003) and S. agalactiae, a common veterinary pathogen (Wu et al. 2008) were also investigated in terms of DNA storage stability on filter paper. FTA cards was shown to be an excellent tool for long-term DNA storage and archiving (up to 44 months) for avian (Smith and Burgoyne 2004) and porcine DBS (Fowler et al. 2012). Fowler et al. (2012) showed that DNA extracted from FTA cards was of good quality to amplify the whole genome and to perform the meaningful single nucleotide polymorphism chip studies even after three years of blood spotting. Venkatesh and Gopal (2018) showed that dried milk could be stored for up to a month at room temperature for the further detection of A1/A2 variants of β-casein using PCR.

Some other high and low molecular weight substances recovery was checked during storage studies of dried samples (Table 2). PAGs were stable for 14 days at 4 °C in dried blood, whereas storage at room temperature caused 22–34% reduction (Sun et al. 2013). Lysosomal enzymes activity did not change much after DBS storage at 4 °C for 6 months; however, 1 year storage at ambient room temperature (20 °C) caused about 20% reduction of activity for all investigated enzymes, except β-glucuronidase (Sewell et al. 2012). Antibiotic enrofloxacin and its metabolite ciprofloxacin were stable in dried blood samples for 4 weeks at -20 °C, + 4 °C or room temperature (Posyniak et al. 2002). Mohamed et al. (2012) demonstrated immunosuppressant cyclosporine A stability in dried blood spots, stored for 9 days, placed at room temperature in the dark and dry environment. A steroid hormone progesterone in dried whole blood showed a good stability after storing for a few weeks at + 4 °C and -20 °C. However, 30% drop of recovered concentration was observed in 3 months (Chadio et al. 2002). At the same time progesterone recovery from dried milk was stable while samples were kept at + 4 °C (1 month), room temperature (1 month), + 37 °C (1 week) or + 60 °C (24 h) (Samsonova et al. 2017). For fatty acid analysis, animal DBS samples should be stored at -80 °C to maintain stability, which limit their usefulness for field sample collection and shipment (Wood et al. 2022). As it was shown previously in numerous publications on human DBS, to maintain fatty acids storage stability at higher temperatures, and to provide dried samples delivery to a laboratory at ambient temperatures, the sampling cards should be impregnated with stabilising agents in order to prevent oxidative destruction of polyunsaturated fatty acids (Liu et al. 2014). It was shown that chemical elements (Hg, As, Se and Pb) recovery from dried blood samples did not differ much over 1–2 year storage (Lehner et al. 2013; Perkins and Basu 2018). Moeller and Yang (2021) showed that the majority of 50 investigated substances (anabolic steroids, β2-adrenoceptor agonists, corticosteroids, hypoxia inducible factor-1 stabilizers, peroxisome proliferator-activated receptor δ agonists, selective androgen receptor modulators, and aromatase inhibitors), which can be used as doping agents for horses, were quite stable after almost 3 months of DBS storage at ambient temperature.
Dried filter paper samples shipping, as well as wildlife sample collection in the field, can face sampling conditions, temperature, humidity and other changes, and that can potentially effect the sample preservation and quality. Madhanmohan et al. (2016) investigated FTA cards impregnated with FMDV RNA (tongue and foot epithelium samples), collected and posted for long route between cities under ambient conditions during post-monsoon and summer seasons in India. Irrespective of adverse atmospheric temperature (21–45 °C) and relative humidity (20–100%), FMDV genome or serotype could be identified in all samples (22–56 days post-collection). Tissues sampling onto cards can arise issues of oversampling; it can also lead to the necessity of robust protocols for humidity control and tissue sample application in the field (Borisenko et al. 2008). In this matter, the authors did not recommend liver as the tissue source for FTA sampling to recover DNA barcodes. Love Stowell et al. (2018) stressed that biological samples preservation from rare and elusive wildlife species for genomic studies poses many challenges. To prevent contamination and DNA degradation in unfavourable sampling conditions, there should be an ability to dry filter paper samples quickly and completely. The authors discovered quick molding of Nobuto filter paper stripes, even when stored with desiccants, and had concerns that the high yield of total DNA from these stripes was the result of the contamination. On the base of massive collection of DBS samples from wildlife for use in serologic testing, Curry et al. (2014b) evaluated dried samples performance under simulating of potential challenges. The challenges comprised different storage durations and different processing/storage regimes, including freezing or drying. Thus Curry et al. (2014b) summarized key recommendations for collection, processing, storage, and shipping of Nobuto filter strips. The authors recommend dry storage at room temperature or at 4 °C up to 2 years, and for longer periods – storage in frozen condition was recommend. Perkins and Basu (2018) investigated laboratory prepared DBS across a range of temperature, humidity, storage duration changes and showed that mercury concentrations for whole blood and DBS were significantly correlated.

The published results on animal DMS shipping and storage revealed that in most cases dried samples with target analytes, including RNA viral agents, could be transported to a laboratory at ambient conditions or even elevated temperature (37 °C) without lack of stability for 7 days at least, and quite often can be stored for much longer. However, as it was pointed out by some authors, humidity is probably the most critical issue for dried samples storage. At the same time, in spite of humidity and temperature changes under samples shipping and storage, successful stability cases were described, and, at the end of the day, the resistance to surrounding conditions depends of the target analyte’s nature. Anyway, the dry storage is essential to prevent molding and potential membrane/sample contamination. And in this regard, alternative, not natural materials, such as polymer or fiber glass carriers that can survive possible biodegradation, should be taken into consideration.

**DBS samples in veterinary medicine and animal biology: diagnostics, monitoring, surveillance, genetic investigations**

The main applications of DBS technology in veterinary and biology are disease diagnostics, sero-surveillance and genetic investigations. DMS specimens, collected of different animal species, provide rapid sample throughput suitable for large-scale epidemiological investigations, which are supported by serological screening methods and PCR. The use of DBS technology is promising for infectious diseases diagnosis, genotyping and sero-surveillance in livestock and poultry and for the post-vaccination control for serum antibodies. Livestock and poultry air-dried biosamples on filter paper were used for monitoring and diagnosis of foot-and-mouth disease, enzootic leucosis, bluetongue disease, trypanosomosis, brucellosis in cattle, toxoplasmosis and Peste des petits ruminants virus disease in small cattle, Aujeszky disease, porcine reproductive and respiratory syndrome, African swine fever in pigs, avian influenza, Newcastle disease, infectious bronchitis, infectious bursal disease in chickens, and for many others (Table 1). Diagnostic work was in close connection with causative virus geno/serotyping and phylogenetic analysis either (Michaud et al. 2007; Madhanmohan et al. 2013; Jóźwiak et al. 2016; Ball et al. 2016; Goharriz et al. 2017; Manswr et al. 2018). In veterinary studies, much attention was paid to epidemiological surveys of the vector-transmitted animal trypanosomosis prevalence, based on DBS samples (Table 1). Trypanosomosis is an acute concern in African countries that requires reliable surveys of the disease distribution along with causative Trypanosoma species identification (Adams et al. 2006; Brito et al. 2008). DBS can be more effective than liquid samples for Trypanosoma identification among infected and uninfected animals, with use of the serological method (Hopkins et al. 1998). The authors noted that obtaining serum in the field for the native (liquid) sample standard analysis requires much more effort, since it is necessary to take a significant amount of blood from the caudal or jugular vein. Holland et al. (2002) demonstrated a lower cut-off value, a higher specificity and sensitivity while using eluted blood spots in an antibody ELISA detection for tsetse transmitted trypanosomosis. In general, the use of DBS approach in tropical regions, hard-to-access and remote areas is of great practical interest. Epidemiological surveys of the prevalence of tsetse-transmitted bovine trypanosomosis requires reliable surveys of the disease distribution (Smit et al. 2014). Many wild species can
serve as *Trypanosoma* reservoir, so susceptible livestock is at risk to be infected by transmission via vector insects (tsetse flies, triatomines and others), while being close to areas inhabited with wildlife species. Therefore, collection and analysis of DBS samples from wild and domestic animals allows assessing the disease prevalence and distribution area (Ventura et al. 2002; Herrera et al. 2005). In this connection, *Trypanosoma* vector insects are the source of parasite genetic material and the investigation specimen in the form of dried midgut (Boid et al. 1999; Adams et al. 2006; Gill- ingwater et al. 2010) or dry fecal spots (Russomando et al. 1996; Machado et al. 2000; Dorn et al. 2001; Brito et al. 2008; Braz et al. 2008).

Dried samples were also used to purposes not associated with livestock infectious diseases, such as pregnancy diagnosis in pigs (Lin et al. 1988; Chadio et al. 2002) and cows’ progesterone profile (Samsonova et al. 2014, 2017), antibiotic detection in chicks (Posyniak et al. 2002) and avian sexing (Suriyaphol et al. 2014). Dried milk spots were used to detect mastitis pathogens (Wu et al. 2008; Durel et al. 2015). Venkatesh and Gopal (2018) used dairy cows’ dried milk and whole blood spots for casein genotyping (A1/A2 variants of β-casein). Evaluation of the nutritional status of ranging dairy cows (zebu) was based on the amino acids and acyl carnitines detection in dried serum spots (Worku et al. 2021). Sander et al. (2018) detected acylcarnitines accumulation in dried serum spots as a result of inhibited β-oxidation of fatty acids, that was atypical myopathy indication in horses, caused by some maple trees seeds or seedlings ingestion.

According to the published works among all infectious diseases in pets, the main attention was paid to the detection of rabies and canine visceral leishmaniasis in dogs’ dried brain and blood spots, toxoplasmosis in cats’ DBS (Table 1). In Brasil canine visceral leishmaniasis represents a serious public health problem due to its wide distribution and severity of its clinical forms. Extensive epidemiological surveys of the disease supported with native and dried sample collection and analysis were performed (Braga et al. 1998; Cabrera et al. 1999; da Silva et al. 2000; Cortes et al. 2004; Palatnik-de-Sousa et al. 2004; Nunes et al. 2007; Figueiredo et al. 2010a, b). Domestic dogs usually live close to humans and livestock, so they can participate in zoonoses transmission. Epidemiologic studies help to assess the exposure to particular vector-borne pathogens in rural dogs and associated ticks, determine their prevalence, characterize the pathogens with the help of molecular methods and evaluate the risk that these pathogens pose to humans and wildlife (Proboste et al. 2015). DBS samples of dogs and cats were also used for enzymatic diagnosis of lysosomal storage disease (Sewell et al. 2012) and for cyclosporine A detection to control of immune-mediated and allergic disorders (Mohamed et al. 2012).

DBS technology is a very valuable approach to monitoring of wildlife animals diseases. Epidemiological studies usually include the detection of the pathogens presence and the pathogens prevalence determination in animals and/or associated vectors. The sero-surveillance results help to assess the actual infection prevalence in a particular animal population and to predict future epizootics in wildlife and exposure risk for humans, if appropriate. Many wildlife infectious diseases are poorly controlled. Due to the complexity of mass sampling in one day, the probes can be collected and accumulated for a long period. In this matter, hunter- or trapper-harvested animals have been a useful resource for sample collections in wildlife health studies (Yu et al. 2007; Sintasath et al. 2009a, b; Curry et al. 2011; Aston et al. 2014). During this time, the point of samples storage or transportation can arise especially in harsh environment conditions including high humidity, low or very high temperature. Liquid samples need to be frozen, which is a complicated task under field conditions, moreover the transportation of a single sample is unjustified. DBS technology allows solving the problem because the dried samples can be stored throughout the expedition under ambient conditions.

Published works comprise a vast range of diseases monitored in wildlife, including trypanosomosis, plague, brucellosis, toxoplasmosis and many others (Table 1). Brucellosis is difficult to control, for instance, in Arctic caribou and reindeer population in Canada due to the harsh climate and the huge habitat (Curry et al. 2011, 2014b). The DBS approach was used for reindeer brucellosis monitoring: DBS samples were taken onto Nobuto strips from deer killed during the shooting under extreme conditions at temperatures up to −40 °C and then analysed by ELISA (Curry et al. 2011). Livestock are susceptible to this disease either, and the main cause of infection is transmission from wildlife. In addition, human infection danger is not excluded due to insufficient heat treatment of food. Wildlife animals can be resistant to clinical disease, for instance, coyotes are resistant to bacterium *Y. pestis*, causative agent of plague (Abbott et al. 2014), but develop anti–pathogen antibodies, by that means providing a way to monitor the particular disease activity in a region. Carnivores are employed in sero-surveys as sentinel animals due to multiple contact with various rodent species, which resulted in infection with *Y. pestis* via their fleas (Chandler et al. 2018). Similarly, wild boar was used as sentinel species during large-scale bovine tuberculosis surveys (Santos et al. 2018). Wild animals can also be a host of the severe human infections causative agents. Thus, occurrence of Puuimala virus in wild bank voles which causes febrile illnesses in humans as well as hantavirus antibodies prevalence assessment and the virus genetic variability studying was done with the help of Nobuto strips whole blood samples (Ahlm et al. 1997; Alexeyev et al. 1998; Olsson et al. 1999).
2003; Johansson et al. 2008). West Nile virus, (WNV, one of arboviruses spread by an arthropod) has become endemic in North America since 1999 and it is maintained through enzootic transmission between birds and mosquitoes. Humans and other mammals also can be infected after the bite of an infected mosquito. Monitoring pattern with dead bird clusters (dried oral swab samples) (Foss et al. 2016) and serological surveys of WNV-specific antibody prevalence in wild birds (DBS), are the two main ways for tracking WNV activity (Sullivan et al. 2006; Nemeth et al. 2017, 2021). Mosquitoes are the vector insects, which can expectorate viruses in their saliva during sugar feeding. Mosquito saliva dried sample collection on honey-soaked FTA cards is used for arboviruses and other viruses surveillance programs that provide information of viral prevalence and distribution (Hall–Mendelin et al. 2010; Ritchie et al. 2013; van den Hurk et al. 2014; Flies et al. 2015; Johnson et al. 2015; Burkett-Cadena et al. 2016; Kurucz et al. 2014; 2019; Wipf et al. 2019; Birnberg et al. 2020). Burkett-Cadena et al. (2016) showed that this approach has a potential to replace sentinel chickens for arbovirus surveillance programmes. Kurucz et al. (2014) also noted that this new system is capable of detecting of virus circulating in very low levels when no sentinel chickens seroconverted. Molecular detection of other vectors pathogens were also described for dried samples of ticks (Higgins et al. 2000). The identification of the vector insects blood meal dried on filter paper has been used in epidemiological studies of host feeding behaviour and infection status of vector population (Boid et al. 1999; Fall et al. 2012; Reeves et al. 2016; Niare et al. 2017).

DBS technology also provides valuable information for ecological surveys. A large-scale survey project DABSE based on collection and analysis of DBS was launched to monitor the impact of the most dangerous toxicants on wild bird species (Shlosberg et al. 2011). A common sampling technique for all types of birds makes it possible to assess their exposure to pollutants degree by the content of toxicants in the blood, regardless of their size, and without causing serious harm to them. For sampling on a card, 100–200 μl of blood is enough, and the approach allows taking blood even from birds weighing 20 g. Following a unified methodology, researchers from all regions of the world can replenish the database of samples and collect statistics based on the results obtained. Under similar research the most dangerous factors affecting the biological activity and birds health caused by human use of pesticides, insecticides, antibiotics, heavy metals and other xenobiotics can be identified (Trudeau et al. 2007; Shlosberg et al. 2011, 2012; Lehner et al. 2013, 2018, 2020; Perkins and Basu 2018). Marine mammals are also at risk to be exposed to mercury (Hansen et al. 2014) and other environmental anthropogenic contaminants (Griffin et al. 2021), all these arise concern for potential adverse effects on wildlife populations. Thus, McHuron et al. (2019) made a risk assessment of mercury concentration in hair, blood and DBS of marine wild-caught pinnipeds. In the Arctic, landlocked Arctic char was used for assessing mercury exposure as the sentinel fish (Barst et al. 2020). Bottlenose dolphins can be exposed to algal bloom toxins during red tides in coastal area, so these mammals are used as important sentinels to assess toxins exposure with the help of whole blood samples collected in the DBS form (Maucher et al. 2007; Twiner et al. 2011).

Dried biological material can be used for genetic studies, demonstrating the utility of membrane carrier (cards) for specimens collection, shipping, storage and further genetic data gathering. An important direction of DBS technology application is the causative agent sero-/genotyping and phylogenetic analysis (Michaud et al. 2007; Kennedy et al. 2008; Brito et al. 2008; Sintasath et al. 2009a, b; Madhavan et al. 2013; Bhuiyan et al. 2014; LeClaire et al. 2015; Jóźwiak et al. 2016; Ball et al. 2016; Manswr et al. 2018) as well as molecular detection/identification of the pathogen (Adams et al. 2006, 2008). Dried samples found application in populational genetics studies as a convenient instrument of sample collection and investigation (Sacks et al. 2004; Silva et al. 2009; Lall et al. 2010; Kraus et al. 2013; Guerrini et al. 2014; Kashiwagi et al. 2015; Nunziata et al. 2016). Isolation and characterization of DNA microsatellite markers, their genotyping for population genetic studies was also described in other works (Sacks et al. 2004; King et al. 2005; Lucentini et al. 2006; Carr and Appleyard 2008; Heim et al. 2012; Nunziata et al. 2016). Kashiwagi et al. (2015) originally described an underwater collection of manta ray mucus by SCUBA divers for further application on FTA Elute cards for population genetic studies. An interesting application of the insect DNA extracted from dried samples, is insect identification for forensic entomology (fast and accurate estimation of time since death) (Harvey 2005). An investigations of dog leukocyte antigen extracted from DBS collected from dogs and wolves were successfully performed by Kennedy et al. (2008). Another example of such application – is the amplification of endo-β-1,4-glucanase gene from termites (Bujang et al. 2011) and first complete genomic sequence of a rabies virus obtained directly from FTA card (Goharriz et al. 2017). Borisenko et al. (2008) using DNA barcoding as a tool, performed verification of taxonomic identifications in ecological assessment surveys of small mammals (opossum, rodents, bats). Dried samples were also used for collecting, archiving and storage of mammals’ and insects’ genetic material (Smith and Burgoyne 2004; Owens and Szalanski 2005; Lall et al. 2010; Miller et al. 2013).

DBS samples are also useful for solving animal health important issues; for instance, measuring of fatty acids concentration as a valuable parameter in determining optimal dietary intake of nutrients in pigs (Wood et al. 2021a), health assessment of The San Cristóbal Galápagos tortoises (Dass
et al. 2021), African savanna elephants (Wood et al. 2021b), southern white rhinoceroses (Wood et al. 2021c) or assessment of wild-type diet composition and examination of fatty acid status for wild and managed care turtles (Dass et al. 2020; Koutsos et al. 2021). Wood et al. (2021b) showed that fatty acids profile in DBS, whole blood, serum and plasma of elephant were comparable. Vitamin D detection in DBS helps performing wildlife animals’ health assessment (Higgins et al. 2020; Moittié et al. 2020), as well as captive animals’ health evaluation (Michaels et al. 2015; Drake et al. 2017; Jaffe et al. 2019) as possible indication of nutritional metabolic bone disease (NMBD) due to possible vitamin D deficient diet. However, comparing vitamin D level in chimpanzees’ DBS and serum, Moittié et al. (2020) concluded that these samples are not interchangeable and stressed that further studies on DBS evaluation are to be performed. Jaffe et al. (2019) also suggested that vitamin D3 detection in DBS is not yet a useful diagnostic method for corncrakes, due to significant systematic and random bias, although DBS and serum/plasma results were highly correlated. Both authors noted substantial analytical variability regardless of the sample type, and that should be connected with method itself (LC–MS/MS) along with sample pretreatment (sample elution and purification) rather than with poor applicability of DBS technology for vitamin D assay. DBS samples were also used to perform stable carbon isotope fingerprinting of essential amino acids as measures of Arctic char dietary carbon sources (Barst et al. 2020), as well as nitrogen stable isotope analyses of amino acids for determining trophic positions of the fish (Barst et al. 2021). Carbon and nitrogen stable isotopes measured in DBS can provide valuable information for feeding ecology or diet studies (O’Hara et al. 2018). Yee et al. (2013) used FTA cards to collect blood for DNA fingerprinting in order to identify painted and milky stork hybrids in zoo, combining both genetic and morphological data (plumage comparison). Dutra et al. (2020) assessed the welfare of dogs by measuring the relative telomere length, a biomarker of cellular ageing, in oral swabs and DBS. DBS can also be a source of DNA to identify sexes of wild birds, being especially important for ecology, biology and breeding (Gutiérrez-Corchero et al. 2002; Quintana et al. 2009; Asawakarn et al. 2018).

DBS in veterinary and biology world: current trends and future developments

In most publications covering the application of DBS technology, it is noted that the successful control of dangerous infections in livestock and wildlife requires an effective and inexpensive method for collection, shipping and storage of biological samples. In this matter, DBS technology is an important alternative to liquid or frozen biofluids, tissues and other samples. However, in veterinary practice, the technology is not that popular, and is barely recognized in some countries; there are no domestic developments and approved guidelines for the use of dried samples in monitoring programs. The low demand for the technology in veterinary medicine is also associated with cost characteristics of the sampling cards available on the market, such as chemically treated FTA cards for PCR analysis, and convenience of its application to animal species, especially in the field. Mostly, the sampling devices are presented in the form of cellulose-based cards designed for dropwise application of biofluid. Typically, additional procedures and tools are required for blood sampling, which greatly complicates the process and increases the time spent per an individual. This format is of little use for whole blood sampling in wild nature, for these locations the stripes of absorbing material found wider application, such as Nobuto stripes, because of their utility for blood saturation from a puncture or a wound (Table 1). Generally speaking, for veterinary it would be preferable to use the easy-handling and affordable sampling devices that allow absorbing material saturation with blood and other biofluids without dispensers. Existing cellulose filter papers usually facilitate the function of a sample carries with lack information on the amount of absorbed biomaterial and that complicates extraction procedure development. In this regard, alternative non-cellulose materials, such as fiberglass membrane, can provide volumetric microsampling of whole blood and other biofluids, which simplifies assay development (Samsonova et al. 2016, 2017, 2022).

DBS technology has its strengths and weak points, it is noted that there is lack of standardization of terminology and methodology (Smit et al. 2014; Freeman et al. 2018). To provide accurate and reliable results for specific task, dried biosamples should be carefully evaluated vs liquid samples, taking into account analyte types and specimen, types of carrier, analyte extraction and assay conditions, samples storage peculiarities. Nevertheless, the review of the published works demonstrated that dried samples have been successfully used for a large variety of health issues across animal species, including birds, reptiles, amphibians, and other animals with small blood sample volumes. For wider adoption of DBS technology into veterinary practice, the convenient and affordable sampling devices should be supported with standardized procedures and available commercial reagents kits (such as ELISA and PCR), intended for the analysis of dried biological samples. This assists the routine use of DBS technology in veterinary laboratories, and provides an easy access for users from remote areas to animal health control.

Application of DBS technology for sampling, storage, transportation and analysis of biological samples of fauna species, has great potential and needs to be propagated not only in the area of agricultural production, but also for wild nature large-scale epidemiological investigations and survey programs. The combination of DBS and
serological analysis is a major advantage for large surveillance surveys. The control and diagnosis of dangerous diseases in livestock and wildlife, investigation of genetic diversity of causative agents and wildlife inhabitants, biobanking and ecological surveys are among the most important applications of DBS technology in veterinary medicine and biological investigations, since this technique meets the demands of easy collection and transportation of dozens of biological samples from herds and wildlife inhabitants to the laboratory. Animal specimens on filter paper are an economic, dry, non-hazardous way of biosamples shipping from collection site to the reference laboratory, making a good reason for the DBS technique to be widely adopted by veterinarians and biologist in their practice. This review is the first attempt to summarize the applications of DBS technology in veterinary and biology, and we hope that it will help to look deeper into the issue of some important technological and methodological points in the following publications concerning this area.

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References

Abbott RC, Hudak R, Mondesire R, Baeten LA, Russell RE, Rocke TE (2014) A rapid field test for sylvatic plague exposure in wild animals. J Wildl Dis 50:384–388. https://doi.org/10.7589/2013-07-174

Abdelwhab EM, Lüschow D, Harder TC, Hafez HM (2011) The use of FTA® filter papers for diagnosis of avian influenza virus. J Virol Methods 174:120–122. https://doi.org/10.1016/j.jviromet.2011.03.017

Adams E, Hanson RP (1956) A procedure for adsorbing virus neutralizing antibodies on paper disks. J Bacteriol 72:572. https://doi.org/10.1128/jb.72.4.572-572.1956

Adams ER, Malele II, Msangi AR, Gibson WC (2006) Trypanosome identification in wild tsetse populations in Tanzania using generic primers to amplify the ribosomal RNA ITS-1 region. Acta Trop 100:103–109. https://doi.org/10.1016/j.actatropica.2006.10.002

Adams ER, Hamilton PB, Malele II, Gibson WC (2008) The identification, diversity and prevalence of trypanosomes in field caught tsetse in Tanzania using ITS-1 primers and fluorescent fragment length barcoding. Infect Genet Evol 8:439–444. https://doi.org/10.1016/j.meegid.2007.07.013

Afshar A, Dulac GC, Riva J (1992) Comparison of blocking dot ELISA and competitive ELISA, using a monoclonal antibody for detection of bluetongue virus antibodies in cattle. Vet Microbiol 31:33–39. https://doi.org/10.1016/0378-1135(92)90139-k

Afshar A, Thomas FC, Wright PF, Shapiro JL, Shettigara PT, Anderson J (1987) Comparison of competitive and indirect enzyme-linked immunosorbent assays for detection of bluetongue virus antibodies in serum and whole blood. J Clin Microbiol 25:1705–1710. https://doi.org/10.1128/jcm.25.9.1705-1710.1987

Ahlm C, Alexeyev OA, Elgh F, Aava B, Wadell G, Tarnvik A, Juto P, Palo T (1997) High prevalence of hantavirus antibodies in bank voles (Clethrionomys glareolus) captured in the vicinity of households afflicted with nephropathia epidemica. Am J Trop Med Hyg 56:674–678. https://doi.org/10.4269/ajtmh.1997.56.674

Ahmadu B, Lovelace CEA, Samui K (2002) A survey of trypanosomosis in Zambian goats using haematocrit centrifuge technique and polymerase chain reaction. J S Afr Vet Assoc 73:224–226. https://doi.org/10.4102/savaj.v73i4.593

Ahmed HA, MacLeod ET, Hide G, Welburn SC, Picozzi K (2011) The best practice for preparation of samples from FTA®cards for diagnosis of blood borne infections using African trypanosomes as a model system. Parasit Vectors 4:68. https://doi.org/10.1186/1756-3305-4-68

Ahmed T, Uddin MB, Islam MR, Syed Sayem Uddin A, Basu J, Uddin M (2012) Filter paper sampling of blood for the detection of antibodies to Infectious Bursal Disease virus using a commercial ELISA kit. Vet World 5:341–345. https://doi.org/10.5455/vetworld.2012.341-345

Ahmed HA, Picozzi K, Welburn SC, MacLeod ET (2013) A comparative evaluation of PCR-based methods for species-specific determination of African animal trypanosomes in Ugandan cattle. Parasit Vectors 6:316. https://doi.org/10.1186/1756-3305-6-316

Al-Kappany Y, Abbas I, Devleesschauwer B, Dorny P, Jennes M, Cox E (2018) Seroprevalence of anti-Toxoplasma gondii antibodies in Egyptian sheep and goats. BMC Vet Res 14:120. https://doi.org/10.1186/s12917-018-1440-1

Aldo Gaggiaro C, Sutmöller P (1965) The use of serum and blood dried on blotting paper in the detection of foot-and-mouth disease antibody. Br Vet J 121:509–514. https://doi.org/10.1016/s0007-1935(17)40903-1

Alexeyev OA, Ahlm C, Elgh F, Aava B, Palo T, Settgergen B, Tarnvik A, Wadell G, Juto P (1998) A minority of seropositive wild bank voles (Clethrionomys glareolus) show evidence of current Puumala virus infection. Epidemiol Infect 121:419–425. https://doi.org/10.1017/s0950268898001307

Andersson A-M, Reineck HB, Nyman A-K (2015) Quantitative detection of antibodies to Aleutian disease virus in dried blood spots as an estimation of hypergammaglobulinemia in mink. Virol Mycol 4:147. https://doi.org/10.4172/2161-0517.1000147

Andersson A-M, Nyman A-K, Wallgren P (2016) Serodiagnosis of aleutian disease virus infection in mink – short term stability and long term consistency of antibody levels measured by VP2 ELISA. Vet Sci Res Rev 2:23–30. https://doi.org/10.17582/journ al.vscr/2016.2.1.23.30

Andersson A-M, Nyman A-K, Wallgren P (2017) A retrospective cohort study estimating the individual Aleutian disease progress in female mink using a VP2 ELISA and its association to reproductive performance. Prev Vet Med 140:60–66. https://doi.org/10.1016/j.prevetmed.2017.02.010
Asa Avakian AP, Dick JW (1985) Comparison of filter-paper-eluted whole A
Aston EJ, Mayor P, Bowman DD, Mohammed HO, Liotta JL, Kwok O, Ashkar T, Ochilo M (1972) The application of the indirect fluorescent antibodies against foot-and-mouth disease virus (FMDV) in filter paper eluates from pig sera or whole blood by ELISA. J Virol Methods 34:181–192. https://doi.org/10.1016/0166-4934(91)90098-K
Asawakarn S, Teeranuwit I, Watcharaprapong N, Siriwatchaiporn N, Somsai P, Kuldee M, Suriyaphol G, Dhitavat S (2018) Comparison of dried blood spot, buccal swab, clausal swab and feces DNA sources to identify avian sexes by PCR. Thai J Vet Med 48:325–330
Ashkar T, Ochilo M (1972) The application of the indirect fluorescent antibody test to samples of sera and dried blood from cattle in the Lambwe Valley, South Nyanza, Kenya. Bull World Health Organ 47:769–772
Aston EJ, Mayor P, Bowman DD, Mohammed HO, Liotta JL, Kwok O, Dubey JP (2014) Use of filter papers to determine seroreiprovalence of Toxoplasma gondii among hunted ungulates in remote Peruvian Amazon. Int J Parasitol Parasites Wildl 3:15–19. https://doi.org/10.1016/j.ijppaw.2013.12.001
Avakian AP, Dick JW (1985) Comparison of filter-paper-eluted whole blood with serum in fowl cholera serology using the enzyme-linked immunosorbent assay. Avian Dis 29:1277–1280. https://doi.org/10.2307/1590486
Awad F, Baylis M, Jones RC, Ganapathy K (2014) Evaluation of Flinders Technologies Association cards for storage and molecular detection of avian metapneumoviruses. Avian Pathol 43:125–129. https://doi.org/10.1080/03079457.2014.885114
Aysanao A, Mayor P, Mendoza AP, Zariquey CM, Morales EA, Pérez JG, Bowler M, Ventocilla JA, González C, Baldeviano GC, Lescano AG (2017) Molecular epidemiology of trypanosomatids and Trypanosoma cruzi in priamtes from Peru. EcoHealth 14:732–742. https://doi.org/10.1007/s10393-017-1271-8
Ball C, Forrester A, Ganapathy K (2016) Detection of variant infectious bronchitis viruses in Sri Lanka (2012–2015). Arch Virol 161:1697–1699. https://doi.org/10.1007/s00705-016-2831-x
Banks M (1985) Detection of antibodies to Aujeszky’s disease virus in whole blood by ELISA disc. J Virol Methods 12:41–45. https://doi.org/10.1016/0166-4934(85)90006-0
Barst BD, Wooller MJ, O’Brien DM, Santa-Rios A, Basu N, Köck G, Johnson JJ, Muir D (2020) Dried blood spot sampling of landlocked Arctic char (Salvelinus alpinus) for estimating mercury exposure and stable carbon isotope fingerprinting of essential amino acids. Environ Toxicol Chem 39(4):893–903. https://doi.org/10.1002/etc.4686
Barst BD, Muir D, O’Brien MJ, Wooller MJ (2021) Validation of dried blood spot sampling for determining trophic positions of Arctic char using nitrogen stable isotope analyses of amino acids. Rapid Commun Mass Spectrom 35(2):e8992. https://doi.org/10.1002/rcm.8992
Beard C, Brugh M (1977) Use of the Nuboto blood-sampling paper strip for Newcastle disease serology. Avian Dis 21:630–636. https://doi.org/10.2307/1589422
Benson TF, Mickle E (1964) A filter paper disc method for collecting canine blood samples for serological procedures. Cornell Vet 54:331–334
Bevins S, Pappert R, Young J, Schmit B, Kohler D, Baeten L (2016) Effect of storage time and storage conditions on antibody detection in blood samples collected on filter paper. J Wildl Dis 52:478–483. https://doi.org/10.7589/2015-09-242
Bhuiyan AR, Chowdhury EH, Kwiatek O, Parvin R, Rahman MM, Islam MR, Albina E, Liebeau G (2014) Dried fluid spots for peste des petits ruminants virus load evaluation allowing for non-invasive diagnosis and genotyping. BMC Vet Res 10:247. https://doi.org/10.1186/s12917-014-0247-y
Birkneheuer AJ, Marr HS, Warren C, Acton AE, Mucker EM, Humphreys JG, Tucker MD (2008) Cytauxzoon felis infections are present in bobcats (Lynx rufus) in a region where cytauxzoonosis is not recognized in domestic cats. Vet Parasitol 153:126–130. https://doi.org/10.1016/j.vetpar.2008.01.020
Birnberg L, Tenham S, Aranda C, Correa-Fiz F, Talavera S, Bigot T, Eloit M, Busquets N (2020) Viromics on honey-baited FTA cards as a new tool for the detection of circulating viruses in mosquitoes. Viruses 12:274. https://doi.org/10.3390/v12030274
Biswal JK, Subramaniam S, Ranjan R, Pattnaik B (2016) Evaluation of FTA® card for the rescue of infectious foot-and-mouth disease virus by chemical transfection of extracted RNA in cultured cells. Mol Cell Probes 30:225–230. https://doi.org/10.1016/j.mcp.2016.06.002
Boid R, Jones TW, Munro A (1999) A simple procedure for the extraction of trypanosome DNA and host protein from dried blood meal residues of haematopogous diptera. Vet Parasitol 85:313–317. https://doi.org/10.1016/s0304-4017(99)00125-9
Bolais PF, Vignoles P, Pereira PF, Keim R, Arousii A, Ismail K, Dardé ML, Amendoeira MR, Mercier A (2017) Toxoplasma gondii survey in cats from two environments of the city of Rio de Janeiro, Brazil by Modified Agglutination Test on sera and filter-paper. Parasit Vectors 10:88. https://doi.org/10.1186/s13071-017-8027-4
Borisenko AV, Lim BK, Ivanova NV, Hanner RH, Hefert PDN (2008) DNA barcoding in surveys of small mammal communities: a field study in Suriname. Mol Ecol Resour 8:471–479. https://doi.org/10.1111/j.1471-2866.2007.01998.x
Bouté F, El Berbri I, Hormaz V, Boucher J-M, El Manny AB, Traore A, Fihri OF, Petavy A-F, Dakkak A, Umhang G (2017) Use of FTA® card methodology for sampling and molecular characterization of Echinococcus granulosus sensu lato in Africa. Exp Parasit 173:29–33. https://doi.org/10.1016/j.exppara.2016.12.016
Braga MD, Coelho IC, Pompeu MM, Evans TG, MacAuliffe IT, Teixeira MJ, Lima JW (1998) Control of canine visceral leishmaniasis: comparison of results from a rapid elimination program of serum-reactive dogs using an immunoenzyme assay and slower elimination of serum-reactive dogs using filter paper elution indirect immunofluorescence (article in Portuguese). Rev Soc Bras Med Trop 31:419–424. https://doi.org/10.1590/s0037-86821998000500001
Braz LMA, Raiz-Júnior R, Alarcón RS, Gakiya E, Amato-Neto V, Okay TS (2008) Suitability of a rapid DNA isolation and amplification for detection of Trypanosoma cruzi in Triatomia infestans dry fecal spots collected on filter paper. Parasite 15:595–598. https://doi.org/10.1051/parasite/2008154595
Brito CMM, Lima MM, Sarquis O, Pires MQ, Coutinho CFS, Duarte R, Pacheco RS (2008) Genetic polymorphism in Trypanosoma cruzi I isolated from Brazilian Northeast triatomines revealed by low-stringency single specific primer-polymerase chain reaction. Parasitol Res 103:1111–1117. https://doi.org/10.1007/s00439-007-86821-9
Braquet-Cadena ND, Gibson J, Lauth M, Stenn T, Acevedo C, Xue R, McNelly J, Northey E, Hassan HK, Fulcher A, Bingham AM, van Olphen J, van Olphen A, Unnasch TR (2016) Evaluation of
the honey-card technique for detection of transmission of arboviruses in Florida and comparison with sentinel chicken seroconversion. J Med Entomol 53:1449–1457. https://doi.org/10.1093/jme/tjw106

Burridge MJ, Kimber CD, McHardy N (1973) Detection of antibodies to Babesia bigemina in dried blood samples using the indirect fluorescent antibody test. Ann Trop Med Parasitol 67:191–195. https://doi.org/10.1080/00034837.1973.11686876

Cabrera GP, Da Silva VO, Da Costa RT, Reis AB, Mayrink W, Genaro O, Palatnik-de-Sousa CB (1999) The fucose-mannose ligand-ELISA in the diagnosis and prognosis of canine visceral leishmaniasis in Brazil. Am J Trop Med Hyg 61:296–301. https://doi.org/10.4269/ajtmh.1999.61.296

Cardona-Ospina JA, Villalba-Miranda MF, Palechor-Ocampo LA, Mancilla LI, Sepúlveda-Arias JC (2019) A systematic review of FTA cards® as a tool for viral RNA preservation in fieldwork: addressing biosecurity and DNA quality issues in abalone aquaculture. J Vet Diagn Invest 31:381–384. https://doi.org/10.1177/1040122319847451

Carr NC, Appleyard S (2008) Using FTA® Elute MicroCards to address biosecurity and DNA quality issues in abalone aquaculture. Aquac Res 39:1799–1802. https://doi.org/10.1111/j.1365-2109.2008.02055.x

Chadjo S, Xylouri E, Kalogiannis D, Michalopoulos E, Evangelatos S, Menegatos I (2002) Early pregnancy diagnosis in swine by direct radioimmunoassay for progesterone in blood spotted on filter paper. Anim Reprod Sci 69:65–72. https://doi.org/10.1016/S0378-4349(01)00145-2

Chandler JC, Baeten LA, Griffin DL, Gillewski TJ, DeLiberto TJ, Petersen JM, Pappert R, Young JW, Bevins SN (2018) A bead-based flow cytometric assay for monitoring Yersinia pestis exposure in wildlife. J Clin Microbiol 56:e00273-e0318. https://doi.org/10.1128/JCM.00273-18

Chang C, Yamamoto K, Chomel BB, Kasten RW, Simpson DC, Smith CR, Kramer VL (1999) Seroepidemiology of Bartonella vinsonii subsp. berkhoffii infection in California coyotes, 1994–1998. Emerg Infect Dis 5:711–715. https://doi.org/10.3201/eid0505.990514

Chomel BB, Kikuchi Y, Martenson JS, Roelke-Parker ME, Chang C-C, Kasten RW, Foley JE, Laudre J, Murphy K, Swift PK, Kramer VL, O’Brien SJ (2004) Seroprevalence of Bartonella infection in American free-ranging and captive pumas (Felis concolor) and common snapping (Chelydra serpentine) turtles in wild and managed care environments. J Zoo Wildl Med 35:478–484. https://doi.org/10.1637/2016-0187.001009-Reg.1

Cortes S, Rolão N, Ramada J, Campino L (2004) PCR as a rapid and sensitive tool in the diagnosis of human and canine leishmaniasis using Leishmania donovani s.l-specific kinetoplastid primers. Trans R Soc Trop Med Hyg 98:12–17. https://doi.org/10.1016/j.trstmh.2003.08.002

Cortes AL, Montiel ER, Gimeno IM (2009) Validation of Marek’s disease diagnosis and monitoring of Marek’s disease vaccines from samples collected in FTA cards. Avian Dis 53:510–516. https://doi.org/10.1637/8871-041009-Reg.1

Cox A, Tilley A, McDolimba F, Fyfe J, Eissler M, Hide G, Welburn S (2005) A PCR based assay for detection and differentiation of African trypanosome species in blood. Exp Parasitol 111:24–29. https://doi.org/10.1016/j.exppara.2005.03.014

Cox A, Tosas O, Tilley A, Picozzi K, Coleman F, Hide G, Welburn S (2010) Constraints to estimating the prevalence of trypanosome infections in East African zebu cattle. Parasit Vectors 3:82. https://doi.org/10.1186/1756-3305-3-82

Curry PS, Elkin BT, Campbell M, Nielsen K, Hutchins W, Ribble C, Kutz SJ (2011) Filter-paper blood samples for ELISA detection of brucella antibodies in caribou. J Wildl Dis 47:12–20. https://doi.org/10.7589/2009-3558-47.1.12

Curry PS, Ribble C, Sears WC, Hutchins W, Orsel K, Godson D, Lindsay R, Dibernardo A, Kutz SJ (2014a) Blood collected on filter paper for wildlife serology: evaluating storage and temperature challenges of field collections. J Wildl Dis 50:308–321. https://doi.org/10.7589/2012-02-047

Curry PS, Ribble C, Sears WC, Orsel K, Hutchins W, Godson D, Lindsay R, Dibernardo A, Campbell M, Kutz SJ (2014b) Blood collected on filter paper for wildlife serology: evaluating storage and temperature challenges of field collections. J Wildl Dis 50:308–321. https://doi.org/10.7589/2012-06-150

da Silva VO, Borja-Cabrera GP, Correia Pontes NN, de Souza EP, Luz KG, Palatnik M, Palatnik de Sousa CB (2000) A Phase III trial of efficacy of the FML-vaccine against canine kala-azar in an endemic area of Brazil (São Gonçalo do Amarantano, Rn). Vaccine 19:1082–1092. https://doi.org/10.1016/S0264-410x(00)00339-x

Dalerum F, Shults B, Kunkel K (2005) A serologic survey for antibodies to three canine viruses in wolverines (Gulo gulo) from the Brooks Range, Alaska. J Wildl Dis 41:792–795. https://doi.org/10.7589/2009-3558-41.4.792

Dam-Tuxen R, Dahl J, Jensen TH, Dam-Tuxen T, Struve T, Bruun L (2014) Diagnosing Aleutian mink disease infection by a new fully automated ELISA or by counter current immunoelectrophoresis: a comparison of sensitivity and specificity. J Virol Methods 199:53–60. https://doi.org/10.1016/j.jviromet.2014.01.011

Dass K, Koutsos E, Minter LJ, Ange-van Heugten K (2020) Analysis of fatty acid profiles for eastern box (Terrapene carolina carolina) and common snapping (Chelydra serpentina) turtles in wild and managed care environments. J Zoo Wildl Med 51:478–484. https://doi.org/10.1637/2019-0146.0

Dass K, Lewhart GA, Muñoz-Pérez JP, Yépez ML, Loyaola A, Chen E, Páez-Rosas D (2021) Whole blood fatty acid concentrations in the San Cristóbal Galápagos tortoise (Chelonoidis chathamensis), PeerJ 9:e11582. https://doi.org/10.7717/peerj.11582

Dávila AMR, Herrera HM, Schlebinger T, Souza SS, Traub-Cseko YM (2003) Using PCR for unraveling the cryptic epizootiology of livestock trypanosomosis in the Pantanal, Brazil. Vet Parasitol 117:1–13. https://doi.org/10.1016/j.vetpar.2003.08.002

de Almeida P, Ndao M, Meirvenne N, Geerts S (1997) Diagnostic evaluation of PCR in goats experimentally infected with. Acta Trop 66:45–50. https://doi.org/10.1016/S0001-706X(97)30007-3

de Almeida P, Ndao M, Goossens B, Osaer S (1998a) PCR primer evaluation for the detection of trypanosome DNA in naturally infected goats. Vet Parasitol 80:111–116. https://doi.org/10.1016/S0304-4017(98)00205-2

de Almeida P, Ndao M, Van Meirvenne N, Geerts S (1998b) Diagnostic evaluation of PCR on dried blood samples from goats experimentally infected with Trypanosoma brucei brucei. Acta Trop 70:269–276. https://doi.org/10.1016/S0001-706X(98)00031-x

de Clare Bronsvoort BM, von Wissmann B, Fèvre EM, Handel IG, Picozzi K, Welburn SC (2010) No gold standard estimation of the sensitivity and specificity of two molecular diagnostic protocols for Trypanosoma brucei spp. in Western Kenya. PLoS One 5:e8628. https://doi.org/10.1371/journal.pone.0008628

de Oliveira A, David C, Esteves PA, Spilki F, Silva A, Holz C, Simonetti A, Roehe P (2011) Blood or serum collected on filter paper for detection of antibodies to bovine herpesvirus Type 1 (BoHV-1). Acta Sci Vet 39:948

de Kesel PM, Sadones N, Capiau S, Lambert WE, Stove CP (2013) Hemato-critical issues in quantitative analysis of dried blood spots: challenges and solutions. Bioanalysis 5(16):2023–2041. https://doi.org/10.4155/bio.13.156

Demirev PA (2013) Dried blood spots: analysis and applications. Anal Chem 85:779–789. https://doi.org/10.1021/ac303205m

Desloire S, Moro C, Chauve C, Zennier L (2006) Comparison of four methods of extracting DNA from D. gallinae (Acari: Dermanyssidae). Vet Res 37:725–732. https://doi.org/10.1051/vetres:2006031
Dorn PL, Flores J, Braheny B, Gutierrez A, Rosales R, Rodas A, Monroy C (2001) Comparison of polymerase chain reaction on fresh tissue samples and fecal drops on filter paper for detection of Trypanosoma cruzi in Rhodnius prolixus. Mem Inst Oswaldo Cruz 96:503–505. https://doi.org/10.1590/S0074-02762000100400010

Drake GJ, Shea RL, Fidgett A, Lopez J, Christley RM (2017) Provision of ultraviolet basking lights to indoor housed tropical birds and their effect on suspected vitamin D3 deficiency. J Zoo Aquarium Res 5:151–157. https://doi.org/10.1022/jzav.v5s4.283

Dubay SA, Rosenstock SS, Stallknecht DE, Devos JC (2006) Determining prevalence of bluetongue and epizootic hemorrhagic disease viruses in mule deer in Arizona (USA) using whole blood dried on paper strips compared to serum analyses. J Wildl Dis 42:159–163. https://doi.org/10.1898/0090-3558.42.1.159

Durel L, Benoît F, Treilles M, Farre M (2015) Extraction of matthias pathogen DNA from sample collecting cards: practical consequences. J Vet Sci Anim Health 3:202. https://doi.org/10.15774/2348-9790.1.602

Duscher G, Peschke R, Wille-Pizzazz W, Joachim A (2009) Parasites on paper–The use of FTA Elute(R) for the detection of Dirofilaria repens microfilariae in canine blood. Vet Parasitol 161:349–351. https://doi.org/10.1016/j.vetpar.2009.01.007

Dusek RJ, Hall JS, Nashold SW, TeSlaa JL, Ip HS (2011) Evaluation of Nobuto filter paper strips for the detection of avian influenza virus antibody in waterfowl. Avian Dis 55:667–676. https://doi.org/10.1637/9687-021511-ResNote.1

Dutra L, Souza F, Jackson I, Araújo M, Vasconcellos A, Young R (2020) Validating the use of oral swabs for telomere length assessment in dogs. J Vet Behav Clin Appl Res 40:16–20. https://doi.org/10.1016/j.jvber.2020.07.011

El Daous H, Mitoma S, Elhanafy E, Thi Nguyen H, Thi Mai N, Hara A, Duangthaph K, Takezaki Y, Kaneko C, Norimine J, Sekiguchi S (2020) Establishment of a novel diagnostic test for Bovine leukemia virus infection using direct filter PCR. Transbound Emerg Dis 67:1671–1676. https://doi.org/10.1111/tbed.13506

Elmore SA, Huyvaert KP, Bailey LL, Milhous J, Alisauskas RT, Dubay SA, Rosenstock SS, Stallknecht DE, DeVos JC (2006) Detection of West Nile virus antibody in waterfowl. Avian Dis 50:675–678. https://doi.org/10.1637/9687-021511-ResNote.1

Figueiredo FB, Madeira MF, Nascimento LD, Abrantes TR, Mouta-Confort E, Passos SRL, Schubach TMP (2010b) Canine visceral leishmaniasis: study of methods for the detection of IgG in serum and eluate samples. Rev Inst Med Trop Sao Paulo 52:193–196. https://doi.org/10.1590/S0036-46652010000400005

Fliers EJ, Toi C, Weinstein P, Doggett SL, Williams CR (2015) Converting mosquito surveillance to arbovirus surveillance with honey-baited nucleic acid preservation cards. Vector Borne Zoonotic Dis 15:397–403. https://doi.org/10.1089/vbz.2014.1759

Forzán MJ, Wood J (2013) Low detection of ranavirus DNA in wild postmetamorphic green frogs, Rana (Lithobates) clamitans, despite previous or concurrent tadpole mortality. J Wildl Dis 49:879–886. https://doi.org/10.1898/2013-03-051

Foss L, Reisen WK, Fang Y, Kramer V, Padgett K (2016) Evaluation of nucleic acid preservation cards for West Nile virus testing in dead birds. PLoS ONE 11:e0157555. https://doi.org/10.1371/journal.pone.0157555

Fowler KE, Reitter CP, Walling GA, Griffin DK (2012) Novel approach for deriving genome wide SNP analysis data from archived blood spots. BMC Res Notes 5:503. https://doi.org/10.1186/1756-0500-5-503

Freeman JD, Rosman LM, Ratcliffe JD, Strickland PT, Graham DR, Silbergeld EK (2018) State of the Science in Dried Blood Spots. Vet Parasitol 249:879–886. https://doi.org/10.1016/j.vetpar.2018.07.019

Ganapathy K, Ball C, Forrester A (2015) Genotypes of infectious bronchitis viruses circulating in the Middle East between 2009 and 2014. Virus Res 210:198–204. https://doi.org/10.1016/j.virusres.2015.07.019

Geysen D, Delespau V, Geerts S (2003) PCR-RFLP using Ssu-rDNA genomic sequence of a rabies virus from the republic of Tajikistan obtained directly from a Flinders Technology Associates dead bird. PLoS ONE 4:503. https://doi.org/10.1371/journal.pone.000313-8

Gillingwater K, Mamabolo MV, Majiwa PAO (2010) Prevalence of mixed Trypanosoma congolense infections in livestock and tsetse in KwaZulu-Natal, South Africa. J S Afr Vet Assoc 81:219–223. https://doi.org/10.4102/jsava.v81i14.151

Gimeno IM, Dunn JR, Cortes AL, El-Gohary AE-G, Silva RF (2014) Detection and differentiation of CV1988 (Rispens vaccine) from other serotype 1 Marek’s disease viruses. Avian Dis 58:232–243. https://doi.org/10.3382/ajdv.2014-05005

Enderle Y, Foerster K, Burhenne J (2016) Clinical feasibility of dried blood spots: Analytics, validation, and applications. J Pharm Biomed Anal 130:231–243. https://doi.org/10.1016/j.jpba.2016.06.026

Evans TG, Vasconcelos IA, Lima JW, Teixeira JM, McCulliffe IT, Lopes UG, Pearson RD, Vasconcelos AW (1990) Canine visceral leishmaniasis in northeast Brazil: assessment of serodiagnostic methods. Am J Trop Med Hyg 42:118–123. https://doi.org/10.4269/ajtmh.1990.42.118

Fall AG, Diulaté A, Etoré E, Bouyer J, Nduaye TD, Konaté L (2012) The mosquito Aedes (Aedimorphus) vexans arabiensis as a probable vector bridging the West Nile virus between birds and horses in Burkédji (Ferlo, Senegal). Med Vet Entomol 26:106–111. https://doi.org/10.1111/j.1365-2915.2011.00974.x

Figueiredo FB, Madeira MF, Menezes RC, Pscheco RS, Pires MQ, Furtado MC, Pinto AG, Schubach TMP (2010a) Efficacy of an indirect immunofluorescence test in the diagnosis of canine leishmaniosis. Vet J 186:123–124. https://doi.org/10.1016/j.tvjl.2009.06.030
Guerrini M, Genni C, Panayides P, Crabtree A, Zuberogoitia I, Copland AS, Babushkina O, Politi PM, Giunchi D, Barbana F (2014) Large-scale patterns of genetic variation in a female-biased dispersing passerine: the importance of sex-based analyses. PLoS ONE 9:e98574. https://doi.org/10.1371/journal.pone.0098574

Gulas-Wroblewski BE, Kairis RB, Gorchakov R, Wheless A, Murray KO (2021) Optimization of DNA extraction from field-collected mammalian whole blood on filter paper for Trypanosoma cruzi (Chagas disease) detection. Pathog 10:1040. https://doi.org/10.3390/pathogens10081040

Gutiérrez-Corcher f, Arruga V, Sanz L, García García C, Hernandez M, Campos F (2002) Using FTAR cards to store avian blood samples for genetic studies. Their application in sex determination. Mol Ecol Notes 2:75–77. https://doi.org/10.1046/j.1471-8287.2001.00110.x

Hall-Mendelin S, Ritchie SA, Johansen CA, Zborowski P, Cortis G, Dandridge S, Hall RA, van den Hurk AF (2010) Exploiting mosquito sugar feeding to detect mosquito-borne pathogens. Proc Natl Acad Sci U S A 107:11255–11259. https://doi.org/10.1073/pnas.1002040107

Hamblin C, Hedger RS (1982) Blood dried on filter or blotting paper for the detection of antibody against swine vesicular disease virus by enzyme-linked immunosorbent assay. Vet Rec 111:460–461. https://doi.org/10.1136/vr.111.20.460-a

Hansen CM, Huefner K, Gulland F, Wells RS, Balmer BC, Castellini JM, O’Hara T (2014) Use of cellulose filter paper to quantify whole-blood mercury in two marine mammals: validation study. J Wildl Dis 50:271–278. https://doi.org/10.7589/2013-08-214

Harvey ML (2005) An alternative for the extraction and storage of DNA from insects in forensic entomology. J Forensic Sci 50:627–629. https://doi.org/10.1525/JFS2004404

Hattermann K, Soike D, Grund C, Mankertz A (2002) A method to evaluate pathogen DNA in mammalian whole blood on filter paper for Trypanosoma cruzi (Chagas disease). Pathog 10:1040. https://doi.org/10.3390/pathogens10081040

Hem BC, Ivy JA, Latch KE (2012) A suite of microsatellite markers optimized for amplification of DNA from Addax (Addax nasomaculatus) blood preserved on FTA cards. Zoo Biol 31:98–106. https://doi.org/10.1002/zoo.20420

Herrera HM, Norek A, Freitas TPT, Rademaker V, Fernandes O, Jansen AM (2005) Domestic and wild mammals infection by Trypanosoma evansi in a pristine area of the Brazilian Pantanal region. Parasitol Res 96:121–126. https://doi.org/10.1007/s00436-005-1334-6

Higgins JA, Hubalek Z, Halouzka T, Gorchakov R, Wheless A, Murray KO (2021) Optimization of DNA extraction from field-collected mammalian whole blood on filter paper for Trypanosoma cruzi (Chagas disease) detection. Pathog 10:1040. https://doi.org/10.3390/pathogens10081040

Higgins JA, Hubalek Z, Halouzka T, Gorchakov R, Wheless A, Murray KO (2021) Optimization of DNA extraction from field-collected mammalian whole blood on filter paper for Trypanosoma cruzi (Chagas disease) detection. Pathog 10:1040. https://doi.org/10.3390/pathogens10081040

Hopkins JS, Chitambo H, Machila N, Luckins AG, Rae PF, Van Den Bosch P, Eiser MC (1998) Adaptation and validation of antibody-ELISA using dried blood spots on filter paper for epidemiological surveys of tsetse-transmitted trypanosomosis in cattle. Prev Vet Med 37:91–99. https://doi.org/10.1016/S0167-5877(98)00101-9

Hutet E, Chevallier S, Eloit M, Touratier A, Blanquefort P, Albina E (2003) Porcine reproductive and respiratory syndrome antibody detection on filter discs. Rev Sci Tech 22:1077–1085. https://doi.org/10.20506/rst.22.3.1461

Inoue R, Tsukahara T, Sunaba C, Itoh M, Ushida K (2007) Simple and rapid detection of the porcine reproductive and respiratory syndrome virus from pig whole blood using filter paper. J Virol Methods 141:102–106. https://doi.org/10.1016/j.jviromet.2006.11.030

Ippen R, Kozojed V, Jira J (1981) Toxoplasmosis in zoo animals. Folia Parasitol (Praha) 28:109–115

Jacques ALB, Santos MK, Gorziza RP, Limberger RP (2022) Dried matrix spots: an evolving trend in the toxicological field. Forensic Sci Med Pathol 18(1):86–102. https://doi.org/10.1007/s12042-021-00434-5

Jaffe JE, Ferguson A, Michaels CJ (2019) The utility of dried blood spots for the assessment of avian vitamin D3 status compared with plasma analysis. J Zoo Aquarim Res 7:138–143. https://doi.org/10.1016/j.jzooar.2019.01.003

Jaffe JE, Ferguson A, Michaels CJ (2019) The utility of dried blood spots for the assessment of avian vitamin D3 status compared with plasma analysis. J Zoo Aquarim Res 7:138–143. https://doi.org/10.1016/j.jzooar.2019.01.003

Jeffries K, Ryan UM, Irwin PJ (2007) PCR-RFLP for the detection and differentiation of the canine piroplasm species and its use with filter paper-based technologies. Vet Parasitol 144:20–27. https://doi.org/10.1016/j.vetpar.2006.09.022

Jennings-Gaines JE, Edwards WH, Robinson TJ (2021) Determining antibody retention in hemolyzed, bacterially contaminated, and Nobuto filter-paper derived serum utilizing two Brucella abortus fluorescence polarization assays. J Wildl Dis 57:386–392. https://doi.org/10.7589/jwd-20-00021

Johansson P, Olsson GE, Low H-T, Bucht G, Ahlm C, Juto P, Elgh F (2008) Puumula hantavirus genetic variability in an endemic region (Northern Sweden). Infect Genet Evol Mol Epidemiol Evol Genet Infect Dis 8:286–296. https://doi.org/10.1016/j.meegid.2008.01.003

Johnson BJ, Kerlin T, Hall-Mendelin S, van den Hurk AF, Cortis G, Doggett SL, Toi C, Fall K, McMahon JL, Townsend N, Ritchie SA (2015) Development and field evaluation of the sentinel mosquito arbovirus capture kit (SMACK), Parasit Vectors 8:509. https://doi.org/10.1186/s13071-015-1114-9

Jordan CN, Kaur T, Koenen K, DeStefano S, Zajac AM, Lindsay DS (2007) Prevalence of agglutinating antibodies to Toxoplasma gondii and Sarcocystis neurona in beavers (Castor canadensis) and raccoons (Procyon lotor). J Wildl Dis 51:724–728. https://doi.org/10.7589/2013-07-185

Jordan CN, Kaur T, Koenen K, DeStefano S, Zajac AM, Lindsay DS (2007) Prevalence of agglutinating antibodies to Toxoplasma gondii and Sarcocystis neurona in beavers (Castor canadensis) and raccoons (Procyon lotor). J Wildl Dis 51:724–728. https://doi.org/10.7589/2013-07-185

Jordan CN, Kaur T, Koenen K, DeStefano S, Zajac AM, Lindsay DS (2007) Prevalence of agglutinating antibodies to Toxoplasma gondii and Sarcocystis neurona in beavers (Castor canadensis) and raccoons (Procyon lotor). J Wildl Dis 51:724–728. https://doi.org/10.7589/2013-07-185

Jóźwiak M, Wyrostek K, Domańska-Blicharz K, Olszewska-Tomczyk M, Smietanka K, Minta Z (2016) Application of FTA® Cards for detection and storage of avian influenza virus. J Vet Res 60:1–6. https://doi.org/10.1515/jvretres-2016-0001

Karalayou S, Tadelle H, Bsrat A, Abebe N, Hailelesiassie M, Schallig HDFH (2011) Serological evidence of Leishmania donovani infection in apparently healthy dogs using direct agglutination test (DAT) and rK9 dipstick tests in Kafita Humera, north-west Ethiopia. Transbound Emerg Dis 58:255–262. https://doi.org/10.1111/j.1865-1682.2011.01209.x

Kennedy CA, Bierbeck LA, Kimball JJ, Simonsen B, Jordan CN (2021) Use of cellulose filter paper to quantify whole-blood mercury in two marine mammals: validation study. J Wildl Dis 50:271–278. https://doi.org/10.7589/2013-08-214

Kamps AJ, Dubay SA, Langenberg I, Maes RK (2015) Evaluation of trapper-collected Nobuto filter-paper blood samples for distemper and parvovirus antibody detection in coyotes (Canis latrans) and raccoons (Procyon lotor). J Wildl Dis 51:724–728. https://doi.org/10.7589/2014-06-147

Karimuribo ED, Morrison LJ, Black A, Turner CMR, Kambarage DM, Ballingall KT (2011) Analysis of host genetic factors influencing...
African trypanosome species infection in a cohort of Tanzanian Bos indicus cattle. Vet Parasitol 179:35–42. https://doi.org/10.1016/j.vetpar.2011.02.001

Karstad L, Spalatin J, Hanson RP (1957) Application of the paper disc technique to the collection of whole blood and serum samples in studies on eastern equine encephalomyelitis. J Infect Dis 101:295–299. https://doi.org/10.1093/infdis/101.3.295

Kashiwagi T, Maxwell EA, Marshall AD, Christensen AB (2015) Evaluating manta ray mucus as an alternative DNA source for population genetics study: underwater-sampling, dry-storage and PCR success. PeerJ 3:e1188. https://doi.org/10.7717/peerj.1188

Katakurak, Takakura A, Kagitama Y (1992) Application of dried whole blood collected on filter paper disks to ELISA for the detection of Sendai virus and mouse hepatitis virus antibodies in mice. Jikken Dobutsu 41:389–390. https://doi.org/10.1538/examin1978.41.3.389

Katakurak, Luninga C, Chitambo H, Tada Y (1997) Detection of Trypanosoma congolense and T. brucei subspecies in cattle in Zambia by polymerase chain reaction from blood collected on a filter paper. Parasitol Res 83:241–245. https://doi.org/10.1007/s00436005240

Keeler SP, Ferro PJ, Brown JD, Fang X, El-Attrache J, Poulson R, Jack-...
applications. J Nat Conserv 46:89–96. https://doi.org/10.1016/j.jnc.2018.09.004
Lucentini L, Palomba AP, Hovirag L, Mauro N, Panara F (2006) A nondestructive, rapid, reliable and inexpensive method to sample, store and extract high-quality DNA from fish body mucus and buccal cells. Mol Ecol Notes 6:257–260. https://doi.org/10.1111/j.1471-218X.2005.005142.x
Machado EM, Alvarenga NJ, Romana AJ, Grisard EC (2000) A simplified method for sample collection and DNA isolation for polymerase chain reaction detection of Trypanosoma rangeli and Trypanosoma cruzi in triatominine vectors. Mem Inst Oswaldo Cruz 95:863–866. https://doi.org/10.1590/S0074-02762000000600021
Madhanmohan M, Nagendrakumar SB, Manikumar K, Yuvaraj S, Parida S, Srinivasan VA (2013) Development and evaluation of a real-time reverse transcription-loop-mediated isothermal amplification assay for rapid serotyping of foot-and-mouth disease virus. J Virol Methods 187:195–202. https://doi.org/10.1016/j.jviromet.2012.08.015
Madhanmohan M, Yuvaraj S, Manikumar K, Kumar R, Nagendrakumar SB, Rana SK, Srinivasan VA (2016) Evaluation of the flinders technology associates cards for storage and temperature challenges in field conditions for foot-and-mouth disease virus surveillance. Transbound Emerg Dis 63:675–680. https://doi.org/10.1111/tbed.12316
Maldonado J, Valls L, Riera P (2009) Method for rapid detection of swine influenza virus. Vet Rec 165:328. https://doi.org/10.1136/vr.b6105
Manswr B, Ball C, Forrester A, Chantrey J, Ganapathy K (2018) Evaluation of the flinders technology associates cards for storage and temperature challenges in field conditions for foot-and-mouth disease virus surveillance. Transbound Emerg Dis 63:675–680. https://doi.org/10.1111/tbed.12316
Maucher JM, Briggs L, Podmore C, Ramsdell JS (2007) Optimization of blood collection card method/enzyme-linked immunoassay for monitoring exposure of bottlenose dolphin to brevetoxin-producing red tides. Environ Sci Technol 41(2):563–567. https://doi.org/10.1021/es0612605
Maw MT, Yamaguchi T, Kasanga CJ, Terasaki K, Fukushi H (2006) Long-term storage at tropical temperature of dried-blood filter papers for detection and genotyping of RNA and DNA viruses by direct PCR. J Virol Methods 146:257–265. https://doi.org/10.1016/j.jviromet.2007.07.006
Miller G, Carmichael A, Favret C, Scheffer S (2013) Room temperature DNA storage with slide-mounted aphid specimens. Insect Conserv Divers 6:447–451. https://doi.org/10.1111/j.1752-4598.2012.00207.x
Minga UM, Wray C (1992) A disc ELISA for the detection of Salmonella group D antibodies in poultry. Res Vet Sci 52:384–386. https://doi.org/10.1016/0034-5288(92)90043-2
Minga UM, Wray C, Gwakisa PS (1992) Serum, disc and egg ELISA for the serodiagnosis of Salmonella gallinarum and S. enteritidis infections in chickens. Scand J Immunol 36:157–159. https://doi.org/10.1111/j.1365-3083.1992.tb01641.x
Moeller BC, Yang Z (2021) Evaluation of dried blood spots as an alternative sample matrix for equine antidoping analysis. Drug Test Anal 13:386–396. https://doi.org/10.1002/dta.2934
Mohamed R, Mercolini L, Cuennet-Cosandey S, Chavent J, Raggi MA, Peyrou M (2012) Validation of a dried blood spot LC-MS/MS approach for cyclosperin A in cat blood: Comparison with a classical sample preparation. J Pharm Biomed Anal 66:298–305. https://doi.org/10.1016/j.jpba.2012.03.049
Moinard-Ahmed GM, Hassan S, Elhussein A, Salih D (2018) Molecular, serological and parasitological survey of Thelidia annulata in North Kordofan State, Sudan. Vet Parasitol Res Stud Reports 13:24–29. https://doi.org/10.1016/j.vprs.2018.03.006
Moittie S, Graham PA, Barlow N, Dobbs P, Liptovszky M, Redrobe S, White K (2020) Comparison of 25-hydroxyvitamin D concentration in chimpanzee dried blood spots and serum. Vet Clin Pathol 49(2):299–306. https://doi.org/10.1111/vcp.12863
Moscoso H, Thayer SG, Hofacre CL, Kleven SH (2004) Inactivation, storage, and PCR detection of Mycoplasma on FTA filter paper. Avian Dis 48:841–850. https://doi.org/10.1637/7215-060104
Moscoso H, Raybon EO, Thayer SG, Hofacre CL (2005) Molecular detection and serotyping of infectious bronchitis virus from FTA filter paper. Avian Dis 49:24–29. https://doi.org/10.1637/77220
Moscoso H, Alvarado I, Hofacre CL (2006) Molecular analysis of infectious bursal disease virus from bursal tissues collected on FTA filter paper. Avian Dis 50:391–396. https://doi.org/10.1637/7505-011306R.1
Moscoso H, Bruzual JJ, Sellers H, Hofacre CL (2007) FTA liver impressions as DNA template for detecting and genotyping fowl adenovirus. Avian Dis 51:118–121. https://doi.org/10.1637/1005-2086(2007)051[0118:FLADT]2.0.CO;2
Moti Y, Fikru R, Büscher P, Van Den Abbeele J, Duchateau L, Delespes V, Parida S, Srinivasan VA (2013) Development and evaluation of a disc ELISA for Brucella abortus. J Immunol Methods 123:39–43. https://doi.org/10.1016/j.jim.2004.03.014
Muck EM, Dubey JP, Lovelal MJ, Humphreys JG (2006) Seroprevalence of antibodies to Toxoplasma gondii in the Pennsylvania bobcat (Lynx rufus rufus). J Wildl Dis 42:188–191. https://doi.org/10.7589/0090-3585-42.1.1188
Mueller-Annelling L, Gilchrist MJ, Thorne PS (2000) Ehrlichia chafeensis antibodies in white-tailed deer, Iowa, 1994 and 1996.
of dried-blood filter papers. Transbound Emerg Dis 63:379–388. https://doi.org/10.1111/tbed.12295

Rasolontjato FV, Guis H, Rajeev M, Dacheux L, Arivony Nomen-janahary L, Razafigtrimo G, Risafandrantantsoa JT, Cété-Sossah C, Heraud J-M, Andriamandimby SF (2020) Enabling animal rabies diagnostic in low-access areas: Sensitivity and specificity of a molecular diagnostic test from cerebral tissue dried on filter paper. PLoS Negl Trop Dis 14:e0008116. https://doi.org/10.1371/journal.pntd.0008116

Reeves LE, Holderman CJ, Gillett-Kaufman JL, Kawahara AY, Kaufman PE (2016) Maintenance of host DNA integrity in field-preserved mosquito (Diptera: Culicidae) blood meals for identification by DNA barcoding. Parasit Vectors 9:503. https://doi.org/10.1186/s13071-016-1791-z

Reisen WK, Presser SB, Lin J, Enge B, Hardy JL, Emmons RW (1994) Viremia and serological responses in adult chickens infected with western equine encephalomyelitis and St. Louis encephalitis viruses. J Am Mosq Control Assoc 10:54–55

Ritchie SA, Cortis G, Paton C, Townsends M, Shroyer D, Zbrowski P, Hall-Mendelin S, Van Den Hurk AF (2013) A simple non-powered passive trap for the collection of mosquitoes for arbovirus surveillance. J Med Entomol 50:185–194. https://doi.org/10.1603/me12112

Rivas AE, Conley K, Seimon TA, Hollinger C, Knych H, Moore RP, Paré JA (2021) Sarcocystosis in a captive flock of thick-billed parrots (Rhynchopsitta pachyrhyncha) from 2005 to 2016: morbidity, mortality, diagnostics, and management strategies. J Zoo Wildl Med 52:206–216. https://doi.org/10.1111/j.1016/j.2020-00134

Rosypal AC, Pick LD, Hernandez JOE, Lindsay DS (2014) Evaluation of a novel dried blood spot collection device (HemaSpotTM) to test blood samples collected from dogs for antibodies to Leishmania infantum. Vet Parasitol 205:338–342. https://doi.org/10.1016/j.vetpar.2014.07.031

Roy P, Nichimarthu K, Venugopalan AT (1992) A modified filter paper technique for serosurveillance of Newcastle disease. Vet Res Commun 16:403–406. https://doi.org/10.1007/BF01839189

Roy P, Nichimathu K, Venugopalan AT, Dorairajan N, Purushothaman V, Koteeswaran A (1994) Filter paper technique for seromonitoring against infectious bursal disease. Trop Anim Health Prod 26:251–252. https://doi.org/10.1007/BF02240397

Roy P, Nichimathu K, Koteeswaran A, Albert A, Venugopalan AT (1997) Postvaccinal immune response to regimens of Newcastle disease vaccination by filter paper sampling technique. Trop Anim Health Prod 29:20–24. https://doi.org/10.1007/BF02623339

Russoomando G, Rojas de Arias A, Almirón M, Figueroedo A, Ferreira ME, Morita K (1996) Trypanosoma cruzi: polymerase chain reaction-based detection in dried feces of Triatoma infestans. Exp Parasitol 83:62–66. https://doi.org/10.1006/expo.1996.0049

Sacks BN, Brown SK, Ernest HB (2004) Population structure of Californian coyotes corresponds to habitat-specific breaks and illuminates species history. Mol Ecol 13:1265–1275. https://doi.org/10.1111/j.1365-294X.2004.02110.x

Sacks BN, Omelon B, Kasten RW, Chang CC, Sanders RK, Letemre SD (2002) Validation for use with coyotes (Canis latrans) of a commercially available enzyme-linked immunosorbent assay for Dirofilaria immitis. Vet Parasitol 109:45–58. https://doi.org/10.1016/S0304-4017(02)00254-6

Sakai T, Ishii A, Segawa T, Takagi Y, Kobayashi Y, Ito U (2015) Establishing conditions for the storage and elution of rabies virus RNA using FTA® cards. J Vet Med Sci 77:461–465. https://doi.org/10.1292/jvms.14-0227

Salim B, Bakheit MA, Kamaju N, Nakamura I, Sugimoto C (2011) Molecular epidemiology of camel trypanosomiasis based on ITS1 rDNA and RoTat 1.2 VSG gene in the Sudan. Parasit Vectors 4:31. https://doi.org/10.1186/1756-3305-4-31

Samsonova JV, Osipov AP, Kondakov SE (2014) A new dried milk sampling technique and its application for progesterone detection in cows. Vet J 199:471–472. https://doi.org/10.1016/j.tvjl.2013.10.031

Samsonova JV, Chadina AD, Osipov AP, Kondakov SE (2016) Porous membrane strip microsampling: a dried biofluid collection format and application for quantitative enzyme immunoassay. Anal Methods 8:4835–4843. https://doi.org/10.1039/C6AY00724D

Samsonova JV, Osipov AP, Kondakov SE (2017) Strip-dried whole milk sampling technique for progesterone detection in cows by ELISA. Talanta 175:143–149. https://doi.org/10.1016/j.talanta.2017.07.032

Samsonova JV, Saushkin NY, Osipov AP, Yakovlev SS, Rozhdestvenskaya TN (2019a) Dried blood samples for transportation and analysis during poultry post-vaccination control (article in Russian). Poult Chick Prod 21:48–52. https://doi.org/10.30975/2017-4999-2019-21-5-48-52

Samsonova JV, Saushkin NY, Osipov AP, Kondakov SE, Fomina SN, Mischenko AV (2019b) Detection of antibodies against foot-and-mouth disease virus serotypes A, O and Asia-1 by ELISA in strip-dried samples from vaccinated bovines. Appl Biochem Biotechnol 188:491–497. https://doi.org/10.1007/s12010-018-02938-3

Samsonova JV, Saushkin NY, Osipov AP (2021) Dried samples of biological fluids on porous membranes as a promising sample preparation method for biomedical and veterinary diagnostics. J Anal Chem 77(4):410–428. https://doi.org/10.1134/S1061944820040104

Sander J, Terhardt M, Sander S, Janzen N (2018) Use of a standard newborn screening test for the rapid diagnosis of inhibited β-oxidation in atypical myopathy in horses. J Equine Vet Sci 67:71–74. https://doi.org/10.1016/j.ejvs.2018.03.010

Santos N, Nunes T, Fonseca C, Vieira-Pinto M, Almeida V, Gortázar C, Correia-Neves M (2018) Spatial analysis of wildlife tuberculosis based on a serologic survey using dried blood spots, Portugal. Emerg Infect Dis 24:2169–2175. https://doi.org/10.3201/eid2412.171135

Sarangi LN, Naveena T, Rana SK, Surendra KS, Reddy RV, Bajibabu P, Ponanna NM, Sharma GK, Srinivasan VA (2018) Evaluation of a specialized filter-paper matrix for transportation of extended bovine semen to screen for bovine herpesvirus-1 by real-time PCR. J Virol Methods 257:1–6. https://doi.org/10.1016/j.jviromet.2018.03.009

Saushkin NY, Samsonova JV, Osipov AP, Kondakov CE, Efimova MA, Chernov AN (2016a) A new sampling format for the diagnostics of bovine infectious diseases in dried blood spots by ELISA. Moscow Univ Chem Bull 71:253–257. https://doi.org/10.3103/S0027131416040088

Saushkin NY, Samsonova JV, Osipov AP, Kondakov SE, Khammadov NI, Usoltsev KV, Makaev KZ, Chernov AN (2016b) Comparison of PCR and ELISA methods for the detection of bovine leucosis in dried blood spots. Moscow Univ Chem Bull 71:319–323. https://doi.org/10.3103/S0027131416050084

Saushkin NY, Samsonova JV, Osipov AP, Kondakov SE, Lysova ES, Elizarova IA, Kharaetynov KS, Shuralev EA (2018) Strip-dried biofluids for the detection of specific antibodies in small, infected ruminants. Moscow Univ Chem Bull 73:135–137. https://doi.org/10.3103/S0027131418030069

Saushkin NY, Samsonova JV, Osipov AP, Kondakov SE (2019) Strip-dried blood sampling: applicability for bovine leukemia virus detection with ELISA and real-time PCR. J Virol Methods 263:101–104. https://doi.org/10.1016/j.jviromet.2018.11.004

Sazmand A, Eigner B, Mirzaei M, Hekmatimoghaddam SH, Harl J, Duscher GG, Fuehrer H-P, Joachim A (2016) Molecular identification of hemoproteozoan parasites in camels (Camelus dromedarius) of Iran. Iran J Parasitol 11:568–573

Springer
Wolff KL, Hudson BW (1974) Paper-strip blood-sampling technique for the detection of antibody to the plague organism Yersinia pestis. Appl Microbiol 28:323–325. https://doi.org/10.1128/am.28.2.323-325.1974

Wood J, Minter LJ, Stokkopol MK, Bibus D, Ange D, Tollefson TN, Fellner V, Ange-van Heugten K (2021a) Investigation of dried blood spot cards for fatty acid analysis using porcine blood. Vet Med Int 2021:6624751. https://doi.org/10.1155/2021/6624751

Wood J, Minter LJ, Bibus D, Stokkopol MK, Fellner V, Ange-van Heugten K (2021b) Comparison of African savanna elephant (Loxodonta africana) fatty acid profiles in whole blood, whole blood dried on blood spot cards, serum, and plasma. PeerJ 9:e12650. https://doi.org/10.7717/peerj.12650

Worku K, Kechero Y, Janssens GPJ (2021) Measuring seasonal and agro-ecological effects on nutritional status in tropical ranging dairy cows. J Dairy Sci 104:4341–4349. https://doi.org/10.3168/jds.2020-18995

Wu J, Li Y, Hu S, Zhou J (2008) Development of a Rapid PCR Test for detection of Streptococcus agalactiae in milk samples collected on filter paper disks. Asian Australasian J Anim Sci 21:124–130. https://doi.org/10.5713/ajas.2008.70076

Yamamoto K, Chomel BB, Lowenstine LJ, Kikuchi Y, Phillips LG, Barr BC, Swift PK, Jones KR, Riley SP, Kasten RW, Foley JE, Pedersen NC (1998) Bartonella henselae antibody prevalence in free-ranging and captive wild felids from California. J Wildl Dis 34:56–63. https://doi.org/10.7589/0090-3558-34.1.56

Yee EYS, Zainuddin ZZ, Ismail A, Yap CK, Tan SG (2013) Identification of hybrids of painted and milky storks using FTA card-collected blood, molecular markers, and morphologies. Biochem Genet 51:789–799. https://doi.org/10.1007/s10528-013-9607-8

Yoon K-J, Cho Y, Kim W, Pitman JS, Brinkman M, Winton C (2010) Experimental and field trial of TEGO™ animal blood collection kit for PRRS testing. In: Proceedings of 2010 AASV Annual Meeting: Implementing Knowledge, March 6–9, 2010, Omaha, USA, pp 211–213

Young ER, Purnell RE (1980) Evaluation of dried blood samples as a source of antibody in the micro ELISA test for Babesia divergens. Vet Rec 106:60–61. https://doi.org/10.1136/vr.106.3.60

Ytrehus B, Rocchi M, Brandsegg H, Turnbull D, Miller A, Pedersen HC, Yoon K-J, Cho Y, Kim W, Pitman JS, Brinkman M, Winton C (2010) Experimental and field trial of TEGO™ animal blood collection kit for PRRS testing. In: Proceedings of 2010 AASV Annual Meeting: Implementing Knowledge, March 6–9, 2010, Omaha, USA, pp 211–213

Young ER, Purnell RE (1980) Evaluation of dried blood samples as a source of antibody in the micro ELISA test for Babesia divergens. Vet Rec 106:60–61. https://doi.org/10.1136/vr.106.3.60

Ytrehus B, Rocchi M, Brandsegg H, Turnbull D, Miller A, Pedersen HC, Kålås JA, Nilsen EB (2021) Louping-ill virus serosurvey of Willow Ptarmigan (Lagopus lagopus lagopus) in Norway. J Wildl Dis 57:282–291. https://doi.org/10.7589/jwd-D-20-00068

Yu C, Zimmerman C, Stone R, Engle RE, Elkins W, Nardone GA, Emerson SU, Purcell RH (2007) Using improved technology for filter-paper-based blood collection to survey wild Sika deer for antibodies to hepatitis E virus. J Virol Methods 142:143–150. https://doi.org/10.1016/j.jviromet.2007.01.016

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