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Review

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Abstract

The present paper summarizes prevalence, epidemiology and clinical disease of natural *Toxoplasma gondii* infections in humans and animals from Egypt. The current situation of toxoplasmosis in Egypt is confusing. There is no central laboratory or group of researchers actively investigating toxoplasmosis in humans or animals, and no reports on the national level are available. Based on various serological tests and convenience samples, *T. gondii* infections appear highly prevalent in humans and animals from Egypt. Living circumstances in Egypt favour the transmission of *T. gondii*. Up to 95% of domestic cats, the key host of *T. gondii*, are infected with *T. gondii*; they are abundant in rural and suburban areas, spreading *T. gondii* oocysts. Many women have been tested in maternity clinics, most with no definitive diagnosis. *Toxoplasma gondii* DNA and IgM antibodies have been found in blood samples of blood donors. Clinical toxoplasmosis in humans from Egypt needs further investigations using definitive procedures. Reports on congenital toxoplasmosis are conflicting and some reports are alarming. Although there are many serological surveys for *T. gondii* in animals, data on clinical infections are lacking. Here, we critically review the status of toxoplasmosis in Egypt, which should be useful to biologist, public health workers, veterinarians and physicians.

Introduction

Toxoplasmosis is a worldwide zoonosis caused by the protozoan *Toxoplasma gondii*, which was first discovered in 1908 in the rodent *Ctenodactylus gundi* at the Pasteur Institute in Tunisia (Nicolle and Manceaux, 1908). At the same time, the parasite was noted in the domestic rabbit (*Oryctolagus cuniculus*) from Brazil (Splendore, 1908). Cats (domestic and wild) are the only definitive hosts of *T. gondii* and are essential in its epidemiology because they are the only hosts that can shed environmentally resistant oocysts (Dubey, 2010).

Approximately one-third of humanity is infected with *T. gondii* worldwide although this varies markedly between populations (Dubey, 2010; Robert-Gangneux and Dardè, 2012). Most infections appear to be asymptomatic in immunocompetent persons; however, the parasite can cause serious disease in unborn fetus and immunocompromised individuals (Peyron *et al.*, 2016). In many animal host species, the infection is also typically subclinical; however, toxoplasmosis can be fatal in many hosts (Dubey, 2010).

Here, we review the detailed prevalence, epidemiological aspects and clinical disease of natural *T. gondii* infection in humans and animals, with focus on domestic animals, from Egypt.

Methods for present review

Egypt is a large African country and has a human population >100 million. It is divided into 27 governorates (Fig. 1). The largest city in Egypt is Cairo, the capital, with a population of >8 million people. Nearly 57% of people live in rural areas, whereas 43% live in urbanized cities (World Population Review, 2019). The Egyptian economy is variable and depends largely on agriculture.

A systematic electronic search of published data was conducted from November 2018 to May 2019. Different databases were consulted including PubMed, Science Direct and Google Scholar using the following keywords: *Toxoplasma gondii*, toxoplasmosis, Egypt, human and animals. Websites of the local Egyptian journals were also incorporated in our search. Libraries of different Egyptian medical and veterinary faculties and institutes were consulted for the old published papers, which are not available as electronic files. Full texts of some earlier published papers were available in the collection of one of us (JPD).

We found numerous reports (>250) on toxoplasmosis in humans and animals from Egypt. Criteria for inclusion were the full text of papers, abstracts only were excluded. After filtering the collected studies, 170 articles met the criteria to be selected for this review. No statistical methods were employed in this study. In the present review, we attempted to incorporate all published reports available to us on natural *T. gondii* infections in Egypt. Some reports of toxoplasmosis in Egypt were included in two reviews on *T. gondii* infections in Africa (Tonouhewa *et al.*, 2017; Rouatbi *et al.*, 2019). The present review is limited to Egypt.

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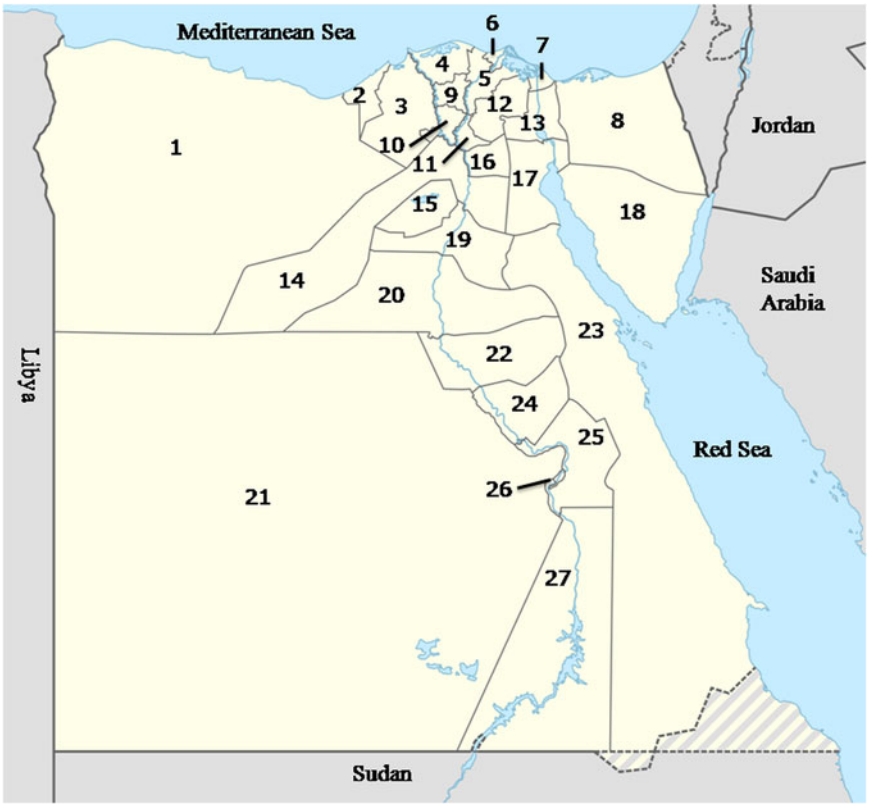

Fig. 1. Map of Egypt including 27 governorates. (1) Matrouh; (2) Alexandria; (3) Beheira; (4) Kafr ElSheikh; (5) Dakahlia; (6) Damietta; (7) Port Said; (8) North Sinai; (9) Gharbia; (10) Menoufiya; (11) Kalubiya; (12) Sharkia; (13) Ismailia; (14) Giza; (15) Fayoum; (16) Cairo; (17) Suez; (18) South Sinai; (19) Beni Suef; (20) Minia; (21) El Wady El Gadeed; (22) Assiut; (23) Red Sea; (24) Sohag; (25) Qena; (26) Luxor; (27) Aswan.

In the present review, detailed serological, parasitological and clinical information on *T. gondii* infections in humans and animals is summarized in the tables and throughout the text. Different serological techniques used in the Egyptian studies are listed in Table 1. Cut-off values for serological tests are listed wherever the authors provided the information. Superscripts in the tables refer to the details of the serological tests provided in Table 1.

History of toxoplasmosis in Egypt

Rifaat and Nagaty (1959) first reported dermal hypersensitivity to *T. gondii* in 15.6% of 334 hospital patients and technical personnel from Cairo using the *T. gondii* skin test. The skin test was one of the first tests developed by Frenkel (1948) for a population survey for *T. gondii* in California, USA; it is a very insensitive test and does not detect acute infection. Subsequently, a highly sensitive and specific test, the dye test (DT), was invented by Sabin and Feldman for the detection of antibodies to *T. gondii*. Beginning in 1962, Rifaat *et al.* used the DT to conduct serological surveys for antibodies to *T. gondii* in humans and other hosts in Egypt. The DT requires the use of live *T. gondii* and is used now only in few laboratories in the world. Rifaat *et al.* (1973*e*) also reported the first case of congenital toxoplasmosis, and they were the first to isolate viable *T. gondii* in Egypt (Rifaat *et al.*, 1971, 1973*a*, 1973*c*, 1976*b*, 1976*c*). Currently, there is no central laboratory or group of researchers actively investigating toxoplasmosis in humans or animals, and unfortunately, no studies are available on the awareness of physicians in Egypt about toxoplasmosis.

Toxoplasmosis in humans

Serological prevalence in general population

In Egypt, there are no centralized data on the national prevalence of *T. gondii*. Most serological reports are based on convenience samples, including in pregnant women, and patients with disorders (Tables 2–5). Generally, little is known of *T. gondii* infection from Sinai and Red Sea governorates, although habits of people living there promote *T. gondii* transmission. Most people living there are Bedouins working mainly in livestock rearing. They usually eat undercooked mutton and drink raw goat and camel milk, in addition to the critical deficiency in hygienic measures and health services. Isolated serological reports in the general population and occupational groups are summarized in Table 2.

Notable among these early surveys is the 16.3% prevalence determined by the DT (Rifaat *et al.*, 1975). Higher seroprevalence is reported in emigrants (37.5%) and abattoir workers (30.9%) compared with 24.4% in hospital attendants (Maronpot and Botros, 1972). More recently, a very high (33–67%) seroprevalence was reported among blood donors (Table 2). Additionally, *T. gondii* DNA was found in 10% (15/150) of blood donors from Alexandria (El-Geddawi *et al.*, 2018); of them, nine were IgG seropositive and six were seronegative (no IgM testing was done). *Toxoplasma gondii* DNA was also noted in 6% (18/300) of blood donors from Kalubiya governorate. Of them, eight were IgM seropositive (El-Sayed *et al.*, 2016*a*). Authors proposed the acute infection and probability of *T. gondii* transmission during blood transfusion. This is a very high rate of *T. gondii* DNA in the blood of asymptomatic individuals. Caution is needed that the accuracy of PCR assay could affect the results. In addition, no further testing was conducted for the positive cases.

Little is known of *T. gondii* prevalence in children in Egypt. Rifaat *et al.* (1963) tested 356 school children from El Wady El Gadeed governorate using the skin test. Samples were collected from children ⩾12 years. Nine (2.5%) children were positive. In a recent report, *T. gondii* antibodies were found in 13 (2.9%) of 6–16 years old 1615 school children (Bayoumy *et al.*, 2016). In these two studies, there is no distinction between acquired infection in childhood and congenital infection.

Data on convenience samples in pregnant women from Egypt attending private health clinics are shown in Table 3. Screening sera for toxoplasmosis is routinely done for pregnant women in

Table 1. Details of serological tests used for the detection of *T. gondii* antibodies in animals and humans in Egypt

Test abbreviation	Antigen	Cut-off	Manufacturer	Citation in the present review
Skin test	Soluble	–	In house	Tb2,15,16
Sabin–Feldman dye test DT	Live tachyzoites	Differs	In house	Tb2,3,6,8,11,13,14,15,16,18,19,20,21
Complement fixation test CFT	Soluble	–	NS	Tb 11,19
OnSite Toxo IgG rapid test OTRT	Recombinant	NS	CTK Biotech, CA, USA www.ctkbiotech.com	Tb2,11,13
Slide agglutination test SAT	NS	1:16	In house	Tb11
Enzyme linked fluorescence assay ELFA VIDAS Toxo IgG II kit	Membrane and cytoplasmic *Toxoplasma* antigen (RH strain)	$\geqslant$8 IU ml^{-1}	Biomērieux, Craponne, France www.biomerieux.com	Tb3
Modified agglutination test				
MAT	Formalin-treated whole tachyzoites	Differs	In house	Tb3,11,12,13,14,16,17,18,19
Toxoscreen Direct agglutination DAT	Formalin-treated whole tachyzoites	1:40	Biomērieux, Craponne, France www.biomerieux.com	Tb11,12
Latex agglutination test LAT				
1. Toxocheck-MT	Soluble	1:64	Eiken Chemical, Tokyo, Japan www.eiken.co.jp	Tb8,11,13,15,17,20,21
2. Toxo Latex kit	Soluble	1:2	CamTech medical, UK	Tb11,13,14,15,16
3. LAT	Soluble local antigen	NS	In house	Tb11,13,17
4. LAT	Soluble	1:64	Sigma Scientific Service Co., Cairo, Egypt www.sigmaeg-co.com	Tb3,12
5. Toxo-LAT fumouze kits	Soluble	NS	Fumouze Diagnostics, France www.fumouze.com	Tb3
Indirect haemagglutination test IHA				
1. Toxo-HAI Fumouze kits	Soluble	1:80	Fumouze Diagnostics, France www.fumouze.com	Tb2,3,4,7,11,12,13,15,17,18,19
2. Toxo-HA	Soluble	1:64	Biomērieux, Craponne, France www.biomerieux.com	Tb2,8
3. Toxo-IHA-Fast Kit	Soluble	1:80	ABC Diagnostics, New Damietta, Egypt	Tb13,14
4. IHA	Soluble	1:16	In house	Tb11,18
5. IHA	Soluble	1:64	Behringwerke AG, Marburg, Germany (merged into CSL Behring) www.cslbehring.com	Tb2,3,6,11,13,14,15,16,19,20
Indirect fluorescent antibody test IFA				
1. IFA	Lyophilized tachyzoites (Biomērieux)	1:16	In house	Tb3,4,6,8
2. Toxo-spot IF slides	Formalin-treated whole tachyzoites	1:50	Biomērieux, Craponne, France www.biomerieux.com	Tb2,11,13
3. IFA	Formalin-treated whole tachyzoites	1:16	In house	Tb2,18
4. IFA	Whole tachyzoites	1:64	In house	Tb11,17
5. IFA	NS	1:16	In house	Tb2,3,6,11,13,14,15,16,18
Enzyme linked immunosorbant assay ELISA				

(*Continued*)

Table 1. (*Continued.*)

Test abbreviation	Antigen	Cut-off	Manufacturer	Citation in the present review
1. bioelisaToxo IgG kits	Inactivated	>10 IU ml^{-1}	Biokit, Barcelona, Spain www.biokit.com	Tb3,4
2. *Toxoplasma* IgG ELISA	Whole tachyzoites	⩾1.2	Calbiotek, CA, USA www.calbiotech.com	Tb3,4,11,13,14,15,16
3. ClinotechToxo ELISA IgG Kits	NS	NS	Clinotech Diagnostics and Pharmaceuticals, Richmond, Canada	Tb2,3,4
4. SeraQuest *Toxoplasma* IgG	NS	NS	Quest International, Inc., Florida, USA	Tb4
5. ELISA IgG Kits	NS	⩾1	Pre Check, Inc., Housten, USA www.precheck.com	Tb3,4
6. *Toxoplasma* IgG ELISA Kits	NS	⩾1.5	MyBioSource, CA, USA www.mybiosource.com	Tb3
7. Toxo IgG ELISA Test Kit	Inactivated	8 IU ml^{-1}	Diagnostic Automation/Cortez Diagnostics, Inc., CA, USA www.rapidtest.com	Tb3
8. *Toxoplasma* IgG ELISA kit	NS	>1	BioCheck, Inc., CA, USA www.biocheckinc.com	Tb4,6,7,14
9. *Toxoplasma* IgG ELISA Kit	NS	0.185	MP Biomedicals Diagnostics Division, Orangeberg, NY, USA	Tb4
10. Toxo IgG ELISA kit	Sonicated antigen	>0.343	Human Gesellschaft für Biochemica und Diagnostica mbH, Wiesbaden, Germany	Tb2
11. DRG® *Toxoplasma gondii* IgG Kit	Inactivated	NS	DRG internationals, Inc., USA www.drg-international.com	Tb2,7
12. ID screen toxoplasmosis multispecies indirect ELISA	P30 antigen	NS	ID.Vet, Grabels, France www.id-vet.com	Tb11,13
13. ELISA	*Toxoplasma* total lysate antigen	0.395	In house	Tb11,13
14. ELISA	Recombinant GST-TgSAG2t antigen	Differs	In house	Tb3,11,15,19
15. Indirect ELISA	Recombinant TgGRA7 antigen	NS	In house	Tb3,11,15,17
16. ELISA	Soluble whole tachyzoites	NS	In house	Tb3,11,13,15,16,17,18,19
17. ELISA	Soluble crude antigen	NS	In house	Tb11,13,14,15,16,17,19,21
18. Indirect IgM ELISA	NS	NS	Serion, Würzburg, Germany www.serion-diagnostics.de	Tb3
19. ELISA-IgG	NS	⩾1	Randox, London, UK www.randox.com	Tb3,4
20. ELISA	NS	NS	Pishtaz Teb Diagnostics, Tehran, Iran. www.old.pishtazteb.com	Tb4
21. ELISA	NS	NS	Behringwerke AG, Marburg, Germany (merged into CSL Behring) www.cslbehring.com	Tb4
22. ELISA	NS	⩾1	Chemux Bioscience, Inc., CA, USA www.chemux.com	Tb4,7
23. ETI-TOXO PLUS	NS	NS	DiaSorin, Salugga, Italy www.diasorin.com	Tb2
24. Novalisa ELISA Kits	NS	NS	Nove Tec immunodiagnostica GmbH, Dietzenbach, Germany www.novatec-id.com	Tb3
25. ELISA	NS	10 IU ml^{-1}	IMMUNOSPEC, California, USA www.immunospec.com	Tb5

Tb, table.

Table 2. Seroprevalence of *T. gondii* antibodies in general human population from Egypt

Population	Governorate	No. tested	No. positive (%)	Test	Important findings	Reference
Hospital patients and technical personnel	Cairo	334	54 (15.6)	Skin test	High prevalence (21%) in older age >20 yrs than in younger 10–19 yrs (6.6%). No positives in children <9 yrs. 15/60 (25%) schizophrenic patients were positive	Rifaat and Nagaty (1959)
Students 10–14 yrs	Tahrir province[a]	87	12 (13.8)	Skin test	–	Rifaat *et al.* (1962)
Students >12 yrs	El Wady El Gadeed	356	9 (2.5)	Skin test	–	Rifaat *et al.* (1963)
Different sources	Cairo	505	156 (30.9)	IFA[5]	High prevalence in 80 emigrants (37.5%) than 110 abattoir workers (30.9%) and 315 hospital attendants (24.4%). 19 had high Ab titres (1:256–1:1024), 147 had low titres (⩽1:64)	Maronpot and Botros (1972)
Healthy and hospital attendants of different ages (2–75 yrs) and sexes	Different governorates	823	115 (14.0)	Skin test	Compatibility of the examined population using both tests was not given	Rifaat *et al.* (1975)
		1750	293 (16.8)	DT (1:16)		
Different sources	Dakahlia	86	24 (27.9)	IHA[2]	High prevalence in 21 butchers (38%), 29 poultry breeders (24%), 21 nurses (28.6%), 15 laboratory workers (20%)	Aboul-Enein *et al.* (1983)
Occupational workers	Sharkia	130	15 (19.2)	IHA[5]	9 had high Ab titres (1:256–1:512), high rates in abattoir workers and butchers	El-Ridi *et al.* (1990)
Lactating women	Kalubiya	70	22(31.4)	IFA[2]	Antibodies in milk of 12 (17.1%)	Azab *et al.* (1992)
Abattoir workers	Gharbia	21	11 (52.3)	IHA[5]	7 had 1:64 Ab titre, 3 had 1:256 and 1 had 1:512	Ibrahim *et al.* (1997)
Hospital patients	Benha	500	56 (11.2)	IFA	Random samples	Hamadto *et al.* (1997)
NS	Kalubiya	152	88 (57.9)	ELISA	16 (10.5%) had IgM	Hussein *et al.* (2001)
Blood donors	Dakahlia	260	155 (59.6)	ELISA[10]	Risk assessment	Elsheikha *et al.* (2009)
Housewives	Middle Delta	70	13 (43.3)	ELISA-IgG[23]	8 (26.6%) had IgM. Of them, 1/23 in housewives wearing gloves during meat handling and 7/47 in non-glove-users	El-Tras and Tayel (2009)
Healthy people	Sharkia	50	12 (24.0)	IHA[1]	2 (4%) had IgM	Awadallah (2010)
Blood donors	Dakahlia	230	155 (67.4)	ELISA	24 (10.4%) positive for IgG avidity	Azab *et al.* (2012)
Blood donors	Kalubiya	300	101 (33.5)	ELISA[11]	93 had IgG, 10 had IgM (2 IgM, 8 IgG and IgM), 18 (6%) positive by PCR	El-Sayed *et al.* (2016*a*)
Blood donors	Alexandria	150	98 (65.3)	ELISA[8]	15 (10%) positive by PCR (9 ELISA positive and 6 ELISA negative)	El-Geddawi *et al.* (2018)
Occupational workers	Cairo	127	48 (37.8)	IFA[3]	Workers from pig farms. 15 had high Ab titres (1:512–1:1024)	Barakat *et al.* (2011)
Humans in contact with chickens	Beni-Suef	250	88 (35.2)	IHA[1]	–	Aboelhadid *et al.* (2013)
Occupational workers	NS	127	48 (37.8)	ELISA[3]	17/48 (35.4%) were PCR positive	Hassanain *et al.* (2013)
School children 6–16 yr	El Wady El Gadeed	1615	13 (2.9)	OTRT	–	Bayoumy *et al.* (2016)

yrs, year; Ab, antibody.
[a]Now known as Beheira governorate.

Table 3. Seroprevalence of *T. gondii* antibodies in pregnant women tested in hospitals or private clinics in Egypt

Governorate	No. tested	No. positive (%)	Test	Additional tests	Remarks	Reference
Assiut	97	26 (26.8)	DT (1:4)	None	OGHA. High Ab titres in 1 (4.8%) of 21 young women (15–20 yrs old)	Rifaat *et al.* (1972)
Cairo	200	32 (16.0)	IFA[5]	ELISA	OGHA. 22 of 23 IFA positives were ELISA positive	Azab *et al.* (1983)
Sharkia	34	4 (11.8)	IFA[1]	None	–	El-Ridi *et al.* (1991*b*)
Cairo	600	164 (27.3)	IHA	IFA	Out of IHA positives, 58.5% were IFA positive	Azab *et al.* (1993)
Kalubiya	150	64 (43.0)	IHA[5]	IgM	3 (2%) had IgM. 64 (43%) of their neonates had IgG, 1 (0.6%) had IgM. MFTR 33.3%	El-Nawawy *et al.* (1996)
Dakahlia	20	2 (10.0)	ELISA-IgG[19]	IgM	No IgM positives	Soliman *et al.* (2001)
Suez	358[a]	24 (6.7%)	ELISA-IgG	IgM, Mice bioassay, PCR	46 (12.9%) had IgM. 39 were serconverted. Viable *T. gondii* was isolated from AF 0f 14 out 85 (46+39) positive women by mice bioassay. 17/85 had *T. gondii* DNA in AF samples.	Eida *et al.* (2009)
Kalubiya	181[a]	85 (47.0)	LAT[5]	IgM	Of positives, 63 (34.8%) had IgM	El-Gozamy *et al.* (2009)[b]
Dakahlia	101	51 (51.4)	ELISA[14] (0.039)	None	–	Ibrahim *et al.* (2009)
Sharkia	25	4 (16.0)	IHA[1]	IgM	2 (8%) had IgM	Awadallah (2010)
Fayoum	59	27 (45.8)	ELISA-IgG[3]	IgM, PCR	Normal pregnant with bad obstetric history. 18 (30.5%) had IgM, 32.2% were PCR positive	Ghoneim *et al.* (2010)
Sharkia	100	30 (30.0)	IHA-IgG[1]	IgM	10 (10%) had IgM	Abd El-Ghany and Amin (2012)[b]
Menoufiya	323	218 (67.5)	ELFA-IgG	IgM, IgG-avidity, PCR	No seroconversion during pregnancy had occurred. 9 (2.8%) had IgM, of them 1 had low IgG avidity. Viable *T. gondii* was isolated from this case by mouse bioassay.	El Deeb *et al.* (2012)[b]
Kalubiya	60	29 (48.3)	LAT[4]	PCR	12 (40%) of seropositives were PCR positive.	Khater *et al.* (2013)
Sharkia	100	71 (71.0)	IHA-IgG[1]	IgM	19 (19%) had IgM	Ahmed *et al.* (2014)[b]
Dakahlia	103	44 (42.7)	ELISA-IgG[2]	IgM	3 (2.9%) had IgM	El-Tantawy *et al.* (2014)
Minia	120	8 (6.6)	ELISA-IgG[2]	IgM	2 (1.6%) had IgM	Kamal *et al.* (2015)
Alexandria	382	221 (57.9)	ELISA-IgG[5]	None	–	Bassiony *et al.* (2016)[b]
Beni Suef	300	46 (15.3)	ELISA-IgG[24]	IgM	Multiparous pregnant women with a history of complication. 26 (8.6%) had IgM	Abdel Gawad *et al.* (2017)[b]
Cairo	30	5 (16.6)	ELISA-IgM[1]	Western-blot-IgM, PCR	History of abnormal pregnancy. 9 (30%) were immunoblot positive, 6 (20%) were PCR positive	Abo Hashim and Attya (2017)
Cairo, Kalubiya, Sharkia	57	22 (38.6)	ELISA-IgG[6]	IgM	4 (7%) had IgM	Abou Elez *et al.* (2017)[b]
Alexandria	101	13 (12.8)	ELFA-IgG	None	–	El-Shqanqery *et al.* (2017)[b]
Beheira	34	10 (29.4)				
Gharbiya	78	21 (26.9)				
Menoufiya	376	124 (32.9)				
Kalubiya	78	21 (26.9)				
Fayoum	26	20 (76.9)				
Total	693	209 (30.1)				
Kafr ElSheikh	113	5 (4.4)	ELISA-IgM[18]	None	–	Elmonir *et al.* (2017)[b]
Menoufiya, Gharbiya	364	123 (33.7)	ELISA[14] (0.039)	RT-PCR	11.8% were PCR positive	Ibrahim *et al.* (2017)[b]
Sohag	350	167 (47.7)	ELISA-IgG[7]	IgM	25 (7.1%) had IgM. 138 (39.4%) of their neonates had IgG, while 5 (1.4%) had IgM. MFTR 25%	Hussein *et al.* (2017)
Giza	388	79 (20.4)	ELISA-IgG[16]	IgM, IgG avidity	43 (11.8%) had IgM, of them 28 (7.2%) had low avidity	Hassanain *et al.* (2018*b*)[b]

MFTR, maternal fetal transmission rate; OGHA, obstetrics and gynaecology hospitals attendants; Ab, antibody; yrs, years.
[a]Including some lymphadenopathy, fever and malaise cases, but the authors did not specify numbers of different cases.
[b]Risk assessment, see Table 6.

Table 4. Diagnosis of *T. gondii* associated abortion, complicated pregnancy and congenital infection in women from Egypt

Population	Pregnancy stage	Governorate	No. tested	No. positive (%)	Test	Additional tests		Remarks	Reference
						IgM	PCR/ blood		
Abortion	NS	Sharkia	62	17 (27.4)	IFA[1]	ND	ND	3 had high Ab titre (1:1024), tachyzoites in histological section. No photographs were given	El-Ridi *et al.* (1991*b*)
Complication			10	3 (30.0)					
Complication	NS	Alexandria	100	65 (65.0)	ELISA-IgG[21]	ND	ND	–	Hammouda *et al.* (1993)
Repeated abortion	NS	Alexandria	100	37 (37.0)	IHA	19 (19.0)	ND	–	Sahwi *et al.* (1995)
Complication	NS	Kalubiya	38	17 (44.7)	ELISA	9 (23.7)	ND	–	Hussein *et al.* (2001)
Complication	NS	Dakahlia	70	57 (81.4)	ELISA-IgG[19]	42 (60.0)	ND	Other complications causes were excluded	Soliman *et al.* (2001)
Abortion	NS	Kalubiya	40	14 (35.0)	ELISA-IgG[1]	12 (30.0)	8 (20.0)	IgG in 6 (40%) and 2 (13%) of neonates from abortion and early labour groups.	El Fakahany *et al.* (2002)
Early labour			10	5 (50.0)		3 (33.0)	5 (50.0)		
CMF			5	1 (20.0)		None	3 (60.0)		
Abortion	1st	Cairo	40	16 (40.0)	ELISA-IgG	10 (25.0)	20 (50.0)	–	Abdel-Hameed and Hassanein (2004)
Abortion	2nd		33	10 (30.3)		9 (27.2)	16 (48.0)		
IUFD	1st		27	4 (14.8)		3 (11.1)	2 (7.4)		
Abortion	NS	Sharkia	25	10 (40.0)	IHA[1]	3 (12.0)	ND	–	Awadallah (2010)
Complication	1st, 2nd	Assiut	100	17 (17.0)	ELISA-IgG[2]	22 (22.0)	ND	5 had IgM only; they were primigravida with early abortions	Shatat *et al.* (2006)[a]
Abortion	NS	Dakahlia	75	75 (100)	NS	75 (100)	58 (77.3)	Authors selected positive IgG and IgM cases only	Abo El Naga *et al.* (2008)[a]
Complication	NS	Zagazig	100	62 (62.0)	ELISA-IgG[20]	47 (47.0)	73 (73.0)	–	El Gamal *et al.* (2013)
Abortion	NS	NS	56	34 (60.7)	ELISA-IgG[3]	ND	9/34 (26.5)	Seropositive cases only were PCR tested	Hassanain *et al.* (2013)
Abortion	1st	Qena	76	35 (46.1)	ELISA-IgG[4]	14 (18.4)	ND	A case had tachyzoites in placental sections. Illustrations are not clear.	Tammam *et al.* (2013)[a]
Abortion	1st	Beni Suef, Cairo	56	17 (30.4)	ELISA-IgG	12 (21.4)	18 (32.1)[b]	–	Hassanain *et al.* (2015)
	2nd		30	8 (26.7)		5 (16.7)	10 (33.3)[b]		
	3rd		15	7 (46.7)		2 (13.3)	6 (40.0)[b]		
CMF	–		5	2 (40.0)		1 (20.0)	1 (20.0)[b]		
Complication	NS	Minia	120	53 (44.1)	ELISA-IgG[2]	29 (24.1)	ND	Other abortifacient causes were excluded	Kamal *et al.* (2015)[a]
Complication	Different	Menoufiya	92	48 (52.2)	ELISA-IgG[5]	9 (9.7)	26 (28.6)[b]	IgG in aborted women ($n = 73$) was 63.9% IgG *vs* 42.9% in those who did not abort ($n = 19$)	Nassef *et al.* (2015)[a]
Abortion	NS	Kalubiya	37	22 (59.5)	ELISA-IgG[22]	7 (18.9)	ND	Other abortifacient causes were excluded. The parasite was not detected in placental sections	Hussein *et al.* (2016)

(*Continued*)

Table 4. (*Continued.*)

Population	Pregnancy stage	Governorate	No. tested	No. positive (%)	Test	Additional tests: IgM	Additional tests: PCR/blood	Remarks	Reference
Complication	Different	Zagazig	100	ND	NS	51 (51.0)	38 (38.0)	35 had low IgG avidity	El-Settawy *et al.* (2016)
Complication	Different	Assiut	182	97 (53.3)	ELISA-IgG[8]	52 (28.6)	ND		Mandour *et al.* (2017)[a]
Abortion	1st	Cairo	139	62 (44.6)	ELISA-IgG[2]	4/77 (5.1)	8/77 (10.2)	IgM and PCR on 77 IgG negatives	Abd El Aal *et al.* (2018)
Abortion	1st	Cairo, Giza	32	12 (37.5)	ELISA-IgG[9]	11 (34.3)	11 (34.4)[b]	-	Barakat *et al.* (2018)
	2nd		21	8 (38.1)		8 (38.1)	8 (38.1)[b]		
	3rd		16	8 (50.0)		6 (37.5)	5 (31.1)[b]		
CMF	-		4	2 (50.0)		1 (25.0)	3 (75.0)[b]		
Abortion	Different	Beni-Suef	35	25 (71.4)	ELISA-IgG[3]	Done	ND	Authors did not give a separate IgG and IgM prevalence	Hassanain *et al.* (2018*a*)

Ab, antibody; ND, not done; NS, not stated; IUFD, intrauterine fetal death; CMF, congenital malformation.
Numbers in parenthesis are percentages.
[a]Risk assessment, see Table 6.
[b]DNA in the placenta.

Egypt. Unfortunately, this screening is conducted mostly in private diagnostic laboratories, which have no systems for archiving the results. In addition, results of this screening are not conclusive because it is based upon the commercially available tests without efficiency verification. Many published reports on toxoplasmosis in pregnant women from Egypt are of limited sample size and have insufficient information on the studied populations. Results are not comparable among different reports because of sample size, diagnostic test used and living conditions of the women tested. There are few data on seroconversion during pregnancy and before pregnancy.

Risk factors associated with T. gondii *infection*

Generally, risk factors of *T. gondii* infection in humans were discussed by many authors (Table 6). Infections were associated with factors such as contact with cats, contact with soil, residence (rural or urban), socioeconomic standards, educational level, ingestion of ready to eat meat products, consumption of undercooked mutton, consumption of raw vegetables, drinking raw milk and consumption of locally prepared Kareish cheese (Elsheikha *et al.*, 2009; El Deeb *et al.*, 2012; Nassef *et al.*, 2015; Hussein *et al.*, 2017). Reports from occupational workers (Table 2) particularly butchers illustrated high *T. gondii* seroprevalence (Abou-Elenin *et al.*, 1983; El-Ridi *et al.*, 1990; Ibrahim *et al.*, 1997). In addition, *T. gondii* antibodies were found in the sera of 48 (37.7%) of 127 workers in pig farms from Cairo and Kalubiya where pigs were raised completely on garbage feeding. Of them, 15 had high (1:512–1:1024) antibody titres (Barakat *et al.*, 2011). *Toxoplasma gondii* DNA was found in 17 (35.4%) out of 48 seropositive occupational workers; however, the authors did not specify their professions (Hassanain *et al.*, 2013). It seems that they tested the same sera used in Barakat *et al.* (2011).

Data linking association between *T. gondii* infection and several disorders such as chronic liver disease and other conditions were too few for a cause–effect relationship (Table 5).

Clinical toxoplasmosis

Congenital

The first report of a congenital toxoplasmosis-like illness in Egypt was in a 1.5-year-old child from Giza (Rifaat *et al.*, 1973*e*). He was admitted to the hospital presenting with marasmus and a mass in the upper part of the abdomen of 1 year's duration. The abdominal examination revealed enlarged liver without ascites or lymph node enlargement. Skull radiography showed microcephaly and bilateral 1–3 mm wide calcification. An extensive central chorio-retinal lesion was also found. The child had a DT *T. gondii* antibody titre of 1:512. His parents were also seropositive (1:128 and 1:64). Despite anti-*Toxoplasma* treatment (not specified), the child died 3 weeks later; post-mortem examination was not performed. In another report, Rifaat *et al.* (1973*a*) first isolated viable *T. gondii* from human placenta. A 30-year-old woman aborted an edematous macerated 22 weeks gestational age fetus. The fetus also had hydrocephaly. Viable *T. gondii* was isolated from the placenta (by mouse inoculation) but not from the fetal brain. Thus, there is no definitive evidence of congenital toxoplasmosis in either of these reports.

Other reports on congenital toxoplasmosis in Egypt are very conflicting and mainly published in local journals which are not widely accessible (Table 4). Most of these reports are based on serological results on single samples from pregnant women. The serologic diagnosis of acute maternal infection based on single serum sample is difficult because IgM antibodies can persist for months and the avidity index might remain low for several

Table 5. Seroprevalence of *T. gondii* antibodies in patients with several disorders

Population	Age range	Governorate	No. tested	No. positive (%)	Test	IgM	Reference
Meningoencephalitis	NS	Cairo	42[a]	10 (26.0)	IFA	ND	Mabrouk and Dahawi (1991)
Cryptogenic epilepsy	2–46 yr	Zagazig	72	25 (34.7)	ELISA-IgG[11]	ND	Abd El-Aal *et al.* (2016)
Non-cryptogenic epilepsy			40	1 (2.5)			
Depression			118	24 (20.3)			
Cryptogenic epilepsy	9 mo-18 yr	Kalubiya	40	8 (20.0)	ELISA-IgG[11]	ND	Eraky *et al.* (2016)
Non-cryptogenic epilepsy			30	None			
Schizophrenia	20–60 yr	Damietta	100	47 (47.0)	ELISA-IgG[22]	ND	Saad *et al.* (2016)
Non-schizophrenic neurodevelopmental disorders	< or >20 yr	Alexandria	188	94 (50.0)	ELISA-IgG[8]	31 (16.5)	Shehata *et al.* (2016)
Neurological disorders without chromosomal anomalies	⩽5 yr	Dakahlia	30	19 (63.3)	ELISA-IgG[8]	11 (36.7)	El-Beshbishi *et al.* (2018)
Down syndrome			30	4 (13.3)		1 (3.3)	
Mental retardation	2 mo-12 yr	Cairo	200	84 (42.0)	IHA[1]	ND	Hamed *et al.* (2018)
Chronic liver disease	50–60 yr	Dakahlia	120	105 (87.5)	ELISA-IgG[25]	16 (13.3)	El-Nahas *et al.* (2014)
Controls			40	6 (15.0)		3 (7.5)	
Chronic liver disease	19–66 yr	Cairo	70	21 (30.0)	PCR-blood	ND	El-Sayed *et al.* (2016*b*)
Controls			50	3 (6.0)			
Tonsilitis	4–20 yr	Zagazig	100	55 (55.0)	IFAT	ND	El-Ridi *et al.* (1989)
Controls			50	12 (24.0)			

ND, not done; NS, not stated; mo, month; yr, year.
[a]Pathogenic bacteria were excluded.

Table 6. Risk factors of *T. gondii* seroprevalence in human population in Egypt

Population	No. tested	No. positive (%)	Risk factors	Reference
Complication	100	17 (17.0)	Rural areas and previous abortion	Shatat *et al.* (2006)
Complication	75	58 (77.3)	20–25 years old, urban areas, previous abortion and contact with soil	Abo El Naga *et al.* (2008)
Normal pregnant	181	85 (47.0)	36–40 years old, rural areas and various disorders	El-Gozamy *et al.* (2009)
Blood donors	260	155 (59.6)	30 years old or more, rural areas, bad hand hygiene, consumption of meat byproducts and unwashed vegetables, drinking municipal water, no education, and contact with cats, different animals and soil	Elsheikha *et al.* (2009)
Abortion	100	30 (30.0)	Contact with soil and consumption of meat byproducts	Abd El-Ghany and Amin (2012)
Normal pregnant	323	218 (67.5)	30–39 years old, urban areas, low economic status, no knowledge about transmission modes, drinking raw milk, consumption of undercooked meat and unwashed vegetables, and contact with cats, farm animals and soil	El Deeb *et al.* (2012)
Abortion	76	35 (46.1)	<25 years old, rural areas and multigravida	Tammam *et al.* (2013)
Normal pregnant	100	71 (71.0)	31–35 years old, previous abortion, contact with cats and soil, and consumption of raw milk and homemade cheese	Ahmed *et al.* (2014)
Complication	120	46 (38.3)	26–30 years old, rural area, low socioeconomic level, housewives, contact with soil, and consumption of undercooked meat and raw vegetables	Kamal *et al.* (2015)
Abortion	92	48 (52.2)	31–40 years old, rural areas, contact with cats and soil, and consumption of undercooked meat	Nassef *et al.* (2015)
Normal pregnant	382	221 (57.9)	35–44 years old, contact with cats and multigravida	Bassiony *et al.* (2016)
Normal pregnant	300	46 (15.3)	30–40 years old, rural areas, 3rd pregnancy trimester and workers	Abdel Gawad *et al.* (2017)
Normal pregnant	57	22 (38.6)	>30 years old and no knowledge about transmission modes	Abou Elez *et al.* (2017)
Normal pregnant	113	5 (4.4)	17–25 years old, contact with soil and drinking unhygienic water	Elmonir *et al.* (2017)
Normal pregnant	693	209 (30.1)	Previous abortion, contact with cats and soil, and consumption of undercooked meat	El-Shqanqery *et al.* (2017)
Normal pregnant	350	165 (47.1)	20–30 years old, living in rural areas, unhealthy houses, low socioeconomic level, contact with cats, handling raw meat and consumption of raw milk	Hussein *et al.* (2017)
Normal pregnant	364	123 (33.7)	>25 years old, contact with cats, farm animals and soil, and consumption of undercooked mutton	Ibrahim *et al.* (2017)
Complication	182	97 (53.2)	>30 years old, rural areas, contact with soil, consumption of undercooked meat or viscera and raw milk, and bad hand hygiene	Mandour *et al.* (2017)
Normal pregnant	388	79 (20.4)	35–39 years old, rural areas, contact with cats and farm animals, previous abortion, taking immunosuppressive drugs and consumption of raw vegetables	Hassanain *et al.* (2018*a*)

Table 7. Seroprevalence of *T. gondii* antibodies in suspected ocular patients from Egypt

Governorate	No. tested	No. positive (%)	Test	Titres	Lesion	Mice inoculation	PCR	Reference
Cairo	1	1 (100)	DT	1:128	Uveitis	ND	ND	Rifaat *et al.* (1973*b*)
Cairo	30	18 (40.0)	IFA[5]	1:16–1:64	NS	ND	ND	Azab *et al.* (1983)
Sharkia	34	9 (26.5)	IFA[1] IHA[5]	281.6–576.7[a]	Anterior and posterior uveitis	ND	ND	El-Ridi *et al.* (1991*a*)
Giza	70	15 (21.1) 36 (51.4)	IFA IHA	NS	Retinochoroiditis	ND	ND	Safar *et al.* (1995)
Alexandria	3	3 (100) 2 (66.6)	ELISA[8]-IgG ELISA[8]-IgM	–	Chorioretinitis	ND	+ve 3/3	Tolba *et al.* (2014)

NS, not stated; ND, not done; +ve, positive.
[a]Antibody titres are given in means.

Table 8. Seroprevalence of *T. gondii* antibodies in cats from Egypt

Source of sera	Governorate	No. tested	No. positive (%)	Test (Cut-off)	Reference
Stray	Cairo and Giza	318	126 (39.6)	DT (1:4)	Rifaat *et al.* (1976*c*)
Stray	Cairo	177	105 (58.8)	IFA[1]	Aboul-Magd *et al.* (1988)
Stray	Gharbiya	92	17 (18.5) 19 (20.7)	IHA[2] IFA[1]	Abu-Zakham *et al.* (1989)
House-hold		32	4 (12.5) 5 (15.6)		
Stray kittens	Cairo, Giza and Kalubiya	34	24 (70.6)	LAT[1]	Hassanain *et al.* (2008)
House-hold Kittens		63	32 (50.8)		
Stray	Giza	158	154 (97.4)	MAT (1:5)	Al-Kappany *et al.* (2010)
Stray	Cairo	180	172 (95.5)	MAT (1:5)	Al-Kappany *et al.* (2011)

months (Peyron *et al.*, 2016), thus definitive diagnosis requires the sequential appearance of specific IgM and IgG antibodies in the same sample. Detection of *T. gondii* in amniotic fluid can confirm the diagnosis of congenital toxoplasmosis and has been reported by Eida *et al.* (2009) and El Deeb *et al.* (2012). However, no clinical follow-up was reported.

Although *T. gondii*-infected women can abort, toxoplasmosis is not a common cause of habitual abortion in women (reviewed in Dubey and Beattie, 1988). Numerous women in Egypt who aborted fetuses have been tested for toxoplasmosis (Table 4). In some of the reports, *T. gondii* DNA was detected in placentas or unspecified products of conception. Once again, the accuracy of PCR requires stringent controls to minimize contamination. Caution is needed that the presence of *T. gondii* DNA in placenta does not equate with congenital infection.

An estimate of the rate of congenital toxoplasmosis can be obtained by data on seroconversion of mothers during pregnancy, serological testing of fetus during pregnancy and after parturition, and clinical follow-up of newborn children. There are no concrete data concerning prevalence of congenital toxoplasmosis in Egypt. To confirm congenital infection, sera would be tested at 12 months showing IgG presence or evidence of neo-synthetized antibodies by Western-blot in children blood from birthday or 3 months of age (Robert-Gangneux and Dardé, 2012).

In summary, there is no definitive evidence of toxoplasmosis abortion or definitive diagnosis of congenital toxoplasmosis in any of these cases.

Post-natal clinical toxoplasmosis

Lymphadenopathy, fever and ocular involvement are some of the common symptoms of acquired toxoplasmosis (Peyron *et al.*, 2016). In addition to the report of these symptoms in pregnant women in Egypt discussed by Eida *et al.* (2009), there are few other reports of toxoplasmosis-associated lymphadenopathy from Egypt (Azab *et al.*, 1983; Tolba *et al.*, 2014) based on mainly serologic examination. There are also a few reports of ocular toxoplasmosis in Egypt (Table 7). Rifaat *et al.* (1973*b*) studied the case of an 18-year-old female student who complained of headache and impaired vision in the right eye. Based on the revealed lesions of uveitis altogether with the positive DT titre (1:128), authors diagnosed the case as toxoplasmic uveitis. This case was treated with pyrimethamine and sulfadiazine for 2 weeks. A month

Table 9. Prevalence of *T. gondii*-like oocysts in fecal samples from cats in Egypt

Governorate	No. tested	No. positive (%)	Reference
Cairo and Giza	213	88 (41.3)[a]	Rifaat *et al.* (1976*c*)
Cairo, Giza and Kalubiya	97	12 (12.3)	Hassanain *et al.* (2008)
Giza	158	None[a]	Al-Kappany *et al.* (2010)
Sharkia	50	25 (50.0)[a]	Awadallah (2010)
Kafr El Sheikh	113	10 (9.0)	Khalafalla (2011)
Sharkia	100	2 (2.0)[b]	Abd El-Ghany and Amin (2012)
Kafr El Sheikh	100	2 (2.0)	Elmonir *et al.* (2017)

[a]See comments in the text.
[b]*T. gondii* DNA was isolated from both cases.

Table 10. Seroprevalence of *T. gondii* antibodies in stray dogs from Egypt

Governorate	No. tested	No. positive (%)	Test	Cut-off	Mice bioassay	Reference
Cairo	45	11 (24.4)	DT	1:16	ND	Rifaat *et al.* (1970)
Cairo	82	40 (46.5)	DT	1:4	Yes[a]	Rifaat *et al.* (1977*a*)
Cairo	43	12 (27.9)	DT	1:16	ND	Khaled *et al.* (1982)
Giza	51	50 (98.0)	MAT	1:4	Yes[b]	El Behairy *et al.* (2013)

ND, not done.
[a]Viable *T. gondii* was isolated from the brains of two dogs.
[b]Viable *T. gondii* was isolated from 22 out of 43 hearts of seropositive dogs.

after treatment, lesions regressed, the vision acuity was enhanced. Based on positive serology and the lesion, ocular toxoplasmosis has been reported by others (Azab *et al.*, 1983; El-Ridi *et al.*, 1991*a*; Safar *et al.*, 1995). Recently, Tolba *et al.* (2014) reported three chorioretinitis cases from Alexandria; the three cases were IgG-positive, while a single case had IgM antibodies. No test was performed in aqueous or vitrous humour.

Toxoplasmosis in animals

Toxoplasmosis can cause severe illness in many domestic and wild animal species. It is a common cause of abortion in sheep and goats worldwide (Dubey, 2010). Many species of animals, such as New World primates, Australasian marsupials, Pallas and Sand cats, are highly susceptible to acute toxoplasmosis, whereas cattle, buffaloes and horses are resistant to toxoplasmosis (Dubey, 2010). Additionally, animals appear reservoirs of *T. gondii* infection. Humans become infected postnatally by ingesting food and water contaminated with oocysts shed by felids and by eating undercooked meat. Available information on *T. gondii* infection in domestic animals from Egypt is summarized here.

Cats

The published seroprevalence estimates in cats are highly variable (12.5–97.4%) (Table 8), depending on the life style and age of cats and the serological test. It is noteworthy that five of the six surveys are from Cairo and Giza governorates.

A very high seroprevalence (>95%) of *T. gondii* was reported in stray cats. The specificity of the MAT for cats was confirmed by isolation of viable *T. gondii* (Al-Kappany *et al.*, 2010). Brains, hearts and tongues from 112 seropositive cats were bioassayed individually in mice. *Toxoplasma gondii* was isolated from 83 hearts, 53 tongues and 36 brains. We are not aware of any report of clinical toxoplasmosis in cats from Egypt.

Cats are the key hosts in the epidemiology of *T. gondii* because they are the only hosts that can excrete environmentally resistant oocysts in feces. There is limited information on *T. gondii* oocyst excretion by cats in Egypt (Table 9). Of these, two reports by Rifaat *et al.* (1976*c*) and Al-Kappany *et al.* (2010) need comment. Rifaat *et al.* (1976*c*) found *T. gondii*-like oocysts in feces of 88 (41.3%) of 213 stray cats trapped from Cairo and Giza. A total of 318 cats were trapped, euthanized and blood and feces were collected for *T. gondii* testing. Antibodies to *T. gondii* were found in 126 (39.6%) by the DT. Nearly half of the cats were considered adults based on weights of cats. Out of these 318 cats, feces of 213 cats were tested for coccidian oocysts. Feces with *T. gondii*-like oocysts were bioassayed in mice, and the identity of *Toxoplasma* oocysts was proven by sub-inoculation of infected mouse tissues to clean mice. *Toxoplasma gondii*-like oocysts were found in 88 cats (20 in 6–8 weeks old, six in 9–12 weeks old, seven in 4–5 months old and 55 in cats older than 6 months). Serological results and oocyst excretion were compared in 33 cats; 14 (35.7%) of 33 cats excreting oocysts were seropositive, and 19 (15.8%) were seronegative. Thus, both seropositive and seronegative cats were excreting oocysts. From the results presented, it is uncertain whether the results were based solely on the presence of antibodies in mice fed oocysts or demonstration of *T. gondii* in mouse tissues. If the results were based on serology alone, then data will not exclude the related parasite, *Hammondia hammondi* infection (Dubey, 2010). There are no archived data or specimens for validation. At any rate, this report from Egypt is the highest prevalence of excretion of *T. gondii*-like oocysts compared with reports from other countries (Dubey, 2010).

Al-Kappany *et al.* (2010) did not find *T. gondii* oocysts in feces of 158 stray cats from Giza, probably because most (97.4%) were seropositive to *T. gondii* and had already excreted oocysts. Awadallah (2010) found *T. gondii*-like oocysts in 25 (50%) of 50 cat feces from Sharkia; however, oocysts identity was not confirmed by bioassay or PCR.

Toxoplasma gondii oocysts are excreted only for a short period (<2 weeks) in the life of the cat and by the time cats become seropositive, oocysts have already been excreted. However, cats can re-excrete oocysts more than once in life (Dubey, 2010).

Isolation of T. gondii *oocysts from the environment*

It is technically difficult to isolate *T. gondii* oocysts from running water (Dubey, 2010). However, Elfadaly *et al.* (2018) observed *T. gondii*-like oocysts in seven (2.9%) of 245 water samples collected from ground pumps (water supplies) in rural areas of Giza governorate. The identity of the recovered oocysts was not confirmed. El-Tras and Tayel (2009) tested 30 water samples from irrigation canals by bioassay in mice. It is not clear whether all samples were infected, and if samples were inoculated separately or in pools. After 6 weeks, sera of inoculated mice were tested using direct agglutination test for *T. gondii*; five were reported to be positives; however, the antibody titres were not stated and mice were not tested for viable *T. gondii*. They also bioassayed in kittens' 30 vegetable samples irrigated by the sampled water. Four cats excreted *T. gondii*-like oocysts; however, oocysts infectivity was not reported, and it is not clear if the kittens were tested for *T. gondii* antibodies before use in the experiment. Recently, methods for detection and viability measure of *T. gondii* oocysts were described and they could be employed in Egypt in order to determine the contamination of the environment (Rousseau *et al.*, 2019).

Dogs

Dogs are considered a source of infection for humans because they roll over and eat cat feces among other foods ingested (Frenkel *et al.*, 2003). Antibodies to *T. gondii* have been demonstrated in the sera of dogs and viable *T. gondii* has been isolated from naturally infected dog tissues (Table 10). Nothing is known of clinical toxoplasmosis in dogs from Egypt.

Table 11. Seroprevalence of *T. gondii* antibodies in sheep from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Different	Abattoir, farms	398	47 (12.1)	IFA[5]	Maronpot and Botros (1972)
Beheira	Abattoir	21	7 (33.3)	DT (1:8)	Rifaat *et al.* (1977*b*)
Sharkia		34	11 (32.3)		
Port Said	Abattoir	7	2 (28.5)	DT (1:8)	Rifaat *et al.* (1977*c*)
Ismailia		21	4 (19.0)		
Suez		24	8 (33.3)		
Cairo	NS	100	37 (37.0), 51 (51.0)	SAT, DT	Michael (1977)
		100	40 (40.0), 9 (9.0)	SAT, CFT	
		90	26 (28.8), 23 (25.5)	SAT, IHA[4]	
Menoufiya	Abattoir	54[a]	9 (16.6)	DT (1:8)	Rifaat *et al.* (1978)
Assiut	Abattoir, veterinary hospital	169	115 (67.9)	DT (1:4)	Fahmy *et al.* (1979*b*)
Alexandria	Abattoir	40	29 (72.5)	DT (1:8)	Rifaat *et al.* (1979)
Sharkia	Abattoir	17	5 (29.4)	IHA[5]	El-Ridi *et al.* (1990)
Kafr ElSheikh	Ewes from a farm	102	47 (46.0), 51 (50.0), 50 (49.0)	ELISA[17], IFA[2], DAT	El-Ghaysh and Mansour (1994)
Gharbia	Abattoir	105	52 (49.5)	IHA[5]	Ibrahim *et al.* (1997)
Cairo	Abattoir	300	131 (43.7), 125 (41.7), 110 (37.0), 102 (34.0)	MAT (1:25), ELISA[17], IFA[4], DT	Shaapan *et al.* (2008)
Giza	Farms	320	152 (47.5), 141 (44.0)	IHA, ELISA	Barakat *et al.* (2009)
Sharkia	Abattoir	50	9 (18.0)	IHA[1]	Awadallah (2010)
Fayoum	NS	62	61 (98.4), 56 (90.3)	ELISA[16], DT	Ghoneim *et al.* (2010)
Cairo	Abattoir	280	141 (50.4), 172 (61.4)	LAT[1], ELISA[17]	Hassanain *et al.* (2011)
Sharkia	Farms	100	85 (85.0)	IHA[1]	Abd El-Ghany and Amin (2012)
NS	NS	280	172 (61.4)	ELISA[16]	Hassanain *et al.* (2013)
Dakahlia	NS	292	122 (41.7), 193 (66.1), 181 (62.0)	LAT[3], IHA[1], ELISA[16]	Younis *et al.* (2015)
Qena	Individual, small farms	37	18 (48.7), 21(56.8)	LAT[1], ELISA[15]	Fereig *et al.* (2016)
Kafr ElSheikh		46	32 (69.6), 32 (69.6)		
Menoufiya		28	3 (10.7), 4 (14.3)		
Assiut	Rural areas	50	22 (44.0), 43 (86.0)	LAT[2,] ELISA[2]	Kuraa and Malek (2016)
Cairo, Giza, Kalubiya	NS	254	163 (64.2)	ELISA[17]	El Fadaly *et al.* (2017)
Menoufiya, Gharbia	Public market	170	88 (51.7)	ELISA[14] (0.096)	Ibrahim *et al.* (2017)
Cairo	Ewes from small farms	25	10 (40.0), 7 (28.0)	OTRT, ELISA[12]	Abd El-Razik *et al.* (2018)
Giza		33	20 (60.6), 17 (51.5)		
Skarkia		55	36 (65.4), 34 (61.8)		
Cairo	Abattoir	193	105 (54.4), 9 (48.7)		
Cairo	Abattoir	100	12 (12.0), 20 (20.0)	ELISA[13], IFA[2]	Al-Kappany *et al.* (2018)
Dakahlia		100	27 (27.0), 38 (38.0)		
Sharkia		99	17 (17.1), 34 (34.3)		
Giza		99	26 (26.2), 32 (32.3)		
Ismailia	Abattoir	100	34 (34.0), 33 (33.0)	ELISA, MAT	El-Gawady *et al.* (2018)

[a]Fifty-four were examined: 27 from Menoufiya governorate and 37 from Tahrir province (currently known as Beheira governorate).

Table 12. Diagnosis of *T. gondii* in pregnant or aborted sheep and goats from Egypt

Animal	Governorate	No. tested	Serological test	No. positive (%)	Antibody titres range	Mice bioassay	PCR	Other abortifacient agents	Reference
Pregnant sheep 15 days before parturition with a history of late pregnancy abortions	NS	10	IHA	10 (100)	1:512–1:2048	ND	ND	–ve *Brucella abortus*	Hassanain *et al.* (1992)
Pregnant goats at different stages of pregnancy	Kalubiya	48	IHA-IgG MAT-IgM	17 (35.4) 11 (22.9)	1:128–1:512	Done[a]	ND	ND	Ramadan *et al.* (2007)
Aborted sheep and goats at late stage of pregnancy	Giza	NS	LAT	(100)	NS	ND	+ve 8 lambs and 4 kids	–ve other abortifacient agents[b]	Ahmed *et al.* (2008)
Pregnant sheep from 3 flocks with history of previous abortions	Sharkia	100	IHA[1]-IgG IHA[1]-IgM	85 (85.0) None	1:160–1:2560	ND	ND	ND	Abd El-Ghany and Amin (2012)
Pregnant sheep from a flock suffering from abortion	Kalubiya	30	LAT[4]	16 (53.3)	⩾1:64	Done[c]	12 (40.0)	ND	Khater *et al.* (2013)
Pregnant sheep with history of abortion	Nile Delta	416	IHA[1]-IgM	129 (31.0)	NS	ND	ND	+ve *Brucella melitensis* in 51 (12.2)[d]	Mahboub *et al.* (2013)
Pregnant goats with history of abortion		76		13 (17.1)				+ve *Brucella melitensis* in 28 (36.8)[d]	
Aborted goats	Cairo, Giza and kalubiya	35	DAT	28 (80.0)[e]	1:25–1:400	ND	ND	ND	Attia *et al.* (2017)

ND, not done; NS, not stated; +ve, positive; –ve, negative.
Numbers in parenthesis are percentages.
[a]Viable *T. gondii* was isolated from tissues of two stillborns, see comment in the text.
[b]*Brucella*, *Salmonella*, *Chlamydia* and *Neospora caninum*
[c]Details were not given.
[d]Data are not separated between *T. gondii* and *Brucella melitensis*.
[e]Tachyzoites were found in placental sections, however neither details nor illustrations were given.

Table 13. Seroprevalence of *T. gondii* antibodies in goats from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Different	Abattoir, farms	234	111 (47.4)	IFA[5]	Maronpot and Botros (1972)
Assiut	Abattoir, veterinary hospital	98	53 (54.1)	DT (1:4)	Fahmy *et al.* (1979*b*)
Sharkia	Abattoir	14	4 (28.6)	IHA[5]	El-Ridi *et al.* (1990)
Gharbia	Abattoir	78	38 (48.7)	IHA[5]	Ibrahim *et al.* (1997)
Giza	Small farms	306	182 (59.4), 170 (55.4)	IHA, ELISA	Barakat *et al.* (2009)
Sharkia	Abattoir	50	8 (16.0)	IHA[1]	Awadallah (2010)
Fayoum	NS	24	10 (41.7), 5 (20.8)	ELISA[16], DT	Ghoneim *et al.* (2010)
Giza	Abattoir	230	102 (44.3)	MAT (1:25)	Shaapan *et al.* (2010)
Cairo, Beni-Suef, Sharkia	Herds	182	77 (42.3)	IHA[3]	Abdel-Rahman *et al.* (2012)
Minia	Abattoir	100	64 (64.0)	IHA[1]	Abdel-Hafeez *et al.* (2015)
Dakahlia	NS	81	40 (49.4), 52 (64.2), 41 (50.6)	LAT[3], IHA[1], ELISA[16]	Younis *et al.* (2015)
Qena	Individual, small farms	27	10 (37.0), 13 (48.2)	LAT[1], ELISA[15]	Fereig *et al.* (2016)
Kafr ElSheikh		30	30 (66.7), 30 (66.7)		
Menoufiya		37	33 (8.1), 37 (10.8)		
Assiut	Rural areas	57	27 (47.4), 50 (87.7)	LAT[2], ELISA[2]	Kuraa and Malek (2016)
Cairo, Giza, Kalubiya	NS	293	127 (43.3)	ELISA[17]	El Fadaly *et al.* (2017)
Cairo	Does from small farms	32	10 (31.2), 9 (28.1)	OTRT, ELISA[12]	Abd El-Razik *et al.* (2018)
Giza		22	9 (40.1), 8 (36.3)		
Skarkia		41	24 (56.1), 22 (53.6)		
Cairo	Abattoir	51	28 (53.0), 22 (43.1)		
Dakahlia	Abattoir	100	59 (59.0), 54 (54.0)	ELISA[13], IFA[2]	Al-Kappany *et al.* (2018)
Ismailia	Abattoir	100	32 (32.0), 31 (31.0)	ELISA, MAT	El-Gawady *et al.* (2018)

Table 14. Seroprevalence of *T. gondii* antibodies in camels from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Different	Abattoir, farms	49	3 (6.1)	IFA[5]	Maronpot and Botros (1972)
Ismailia	Abattoir	43	29 (67.4)	DT (1:8)	Rifaat *et al.* (1977*c*)
Assiut	Individual owners	80	12 (15.0)	DT (1:16)	Michael *et al.* (1977)
Menoufiya		80	15 (18.7)		
Matrouh		80	40 (50.0)		
Menoufiya	Abattoir	30	17 (56.7)	DT (1:8)	Rifaat *et al.* (1978)
Assiut	Abattoir, veterinary hospital	119	30 (24.4)	DT (1:4)	Fahmy *et al.* (1979*a*)
Sharkia	Abattoir	19	5 (26.3)	IHA[5]	El-Ridi *et al.* (1990)
Gharbia	Abattoir	36	6 (16.7)	IHA[5]	Ibrahim *et al.* (1997)
Cairo	Abattoir	166	29 (17.4)	MAT (1:25)	Hilali *et al.* (1998)
Cairo	Abattoir	150	[1]27 (18.0), [2]30 (20.0), [3]46 (30.7), [4]41 (27.3)	MAT[a] (1:25)	Shaapan and Khalil (2008)
Assiut	Rural areas	56	20 (35.7), 54 (96.4)	LAT[2], ELISA[2]	Kuraa and Malek (2016)
Kalubiya	Abattoir	120	6 (5.0), 63 (52.6)	IHA[3], ELISA[8]	Ahmed *et al.* (2017)
Cairo, Giza, Kalubiya	NS	34	9 (26.5)	ELISA[17]	El Fadaly *et al.* (2017)

[a]MAT was conducted using formalin-treated whole tachyzoites from different antigen; [1]RH strain, [2]local equine strain, [3]local camel strain and [4]local sheep strain.

Table 15. Seroprevalence of *T. gondii* antibodies in cattle from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Port Said	NS	35	None	Skin test	Rifaat *et al.* (1968)
Different	Abattoir, farms	207	52 (25.1)	IFA[5]	Maronpot and Botros (1972)
Beheira	Abattoir	15	7 (46.6)	DT (1:8)	Rifaat *et al.* (1977*b*)
Dakahlia		60	44 (30.1)		
Sharkia		8	None		
Fayoum		132	28 (21.2)		
Port Said	Abattoir	16	5 (31.2)	DT (1:8)	Rifaat *et al.* (1977*c*)
Ismailia		16	4 (25.0)		
Suez		34	11 (32.2)		
Kalubiya	Abattoir	84	16 (19.0)	DT (1:8)	Rifaat *et al.* (1978)
Gharbia		171	37 (21.6)		
Menoufiya		68	24 (35.2)		
Kafr ElSheikh		50	22 (44.0)		
Dameitta	Abattoir	40	22 (55.0)	DT (1:8)	Rifaat *et al.* (1979)
Alexandria		65	14 (21.5)		
Assiut	Abattoir, veterinary hospital	106	50 (47.0)	DT (1:4)	Fahmy *et al.* (1979*b*)
Sharkia	Abattoir	19	4 (21.4)	IHA[5]	El-Ridi *et al.* (1990)
Gharbia	Abattoir	39	18 (46.2)	IHA[5]	Ibrahim *et al.* (1997)
Sharkia	Veterinary station	93	10 (10.7)	ELISA[14]	Ibrahim *et al.* (2009)
Sharkia	Abattoir	50	6 (12.0)	IHA[1]	Awadallah (2010)
NS	NS	88	17 (19.3)	ELISA[16]	Hassanain *et al.* (2013)
Minia	Abattoir	100	None	IHA[1]	Abdel-Hafeez *et al.* (2015)
Qena	Individual, small farms	225	66 (29.3), 55 (24.4)	LAT[1], ELISA[15]	Fereig *et al.* (2016)
Sohag		76	22 (29.0), 16 (21.1)		
Assiut	Rural areas	56	18 (32.1), 41 (73.2)	LAT[2,] ELISA[2]	Kuraa and Malek (2016)
Cairo, Giza, Kalubiya	NS	45	16 (35.5)	ELISA[17]	El Fadaly *et al.* (2017)

Food animals

Sheep

The estimated sheep population in Egypt is 5.5 million (Food and Agriculture Organization, 2015). Sheep meat is widely consumed in Egypt, especially during religious holidays. The consumption of undercooked dish 'Kabob and kofta' is popular (Hassan-Wassef, 2004), which favours *T. gondii* transmission to humans. Most reports used sera from sheep at abattoirs, while few studies were conducted on sheep in farms (Table 11). In a histological study, *T. gondii* tissue cysts were noted in brain sections of two out of 60 sheep from a herd in Suez governorate (Anwar *et al.*, 2013); we consider the two tissue cysts illustrated in Figure 4 of their paper as *Sarcocystis* cysts (J.P. Dubey, own opinion).

Toxoplasma gondii is an important cause of abortion in sheep worldwide but little is known of its occurrence in sheep from Egypt (Dubey, 2010). Direct evidence of ovine congenital toxoplasmosis was provided by Rifaat *et al.* (1977*a*) who isolated viable *T. gondii* by mouse bioassay from tissues of an aborted lamb. *Toxoplasma gondii* DNA has been demonstrated in aborted fetal tissues (Table 12). Finding *T. gondii* parasites or *T. gondii* DNA only indicates congenital transmission. Histopathological evaluation and exclusion of other causes of abortion are necessary to establish cause–effect relationship. Serological testing of ewes is of little help because high levels of *T. gondii* IgG can persist for months and IgM antibodies have already peaked in aborted ewes (Dubey, 2010).

Goats

Goat population in Egypt is ~4 million. Goats are usually reared within sheep herds. In a popular system in Egypt, particularly in suburban areas, small numbers of goats are kept in houses, and can roam to feed on the garbage along with cats and dogs. Using different serological tests, high *T. gondii* seroprevalence was reported from goats in Egypt (Table 13).

Like sheep, little is known of toxoplasmal abortion in goats from Egypt; available information is summarized in Table 12. Ramadan *et al.* (2007) found IgG antibodies in 17 (35.4%) of 48 pregnant Balady goats from Kalubiya governorate; 11 (22.9%) of them had IgM. Three goats in the mid pregnancy stage were sulfadimidine-treated for 5 successive days, while another three kept untreated as controls. No abortions had occurred in the treated group and the delivered kids were seronegative, while one of the untreated goats delivered two seropositive-stillborns (IgG and IgM). Viable *T. gondii* was isolated from tissues of the stillborns.

Transmission of *T. gondii* to humans by consumption of raw goat milk is of public health significance (Dubey *et al.*, 2014). Consumption of goat milk is popular in Egyptian rural areas. Abdel-Rahman *et al.* (2012) fed eight cats raw milk from eight seropositive goats (four IgG and four IgM positive goats); we are not aware of the validity of the used commercial kits. *Toxoplasma gondii*-like oocysts were found in feces from all cats of the IgM group and one cat from the IgG group; however,

Table 16. Seroprevalence of *T. gondii* antibodies in water buffaloes from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Port Said	NS	51	5 (9.8)	Skin test	Rifaat *et al.* (1968)
Gharbia		60	3 (5.0)		
Different	Abattoir, farms	211	59 (28.0)	IFA[5]	Maronpot and Botros (1972)
Beheira	Abattoir	14	4 (28.5)	DT (1:8)	Rifaat *et al.* (1977*b*)
Dakahlia		60	18 (30.0)		
Sharkia		24	4 (9.5)		
Fayoum		280	83 (29.6)		
Port Said	Abattoir	48	16 (33.3)	DT (1:8)	Rifaat *et al.* (1977*c*)
Ismailia		109	13 (11.9)		
Suez		85	16 (18.8)		
Kalubiya	Abattoir	92	39 (42.4)	DT (1:8)	Rifaat *et al.* (1978)
Menoufiya		98	22 (24.4)		
Assiut	Abattoir, veterinary hospital	212	93 (43.9)	DT (1:8)	Fahmy *et al.* (1979*b*)
Dameitta	Abattoir	193	76 (34.2)	DT (1:4)	Rifaat *et al.* (1979)
Alexandria		80	9 (11.2)		
Sharkia	Abattoir	15	3 (20.0)	IHA[5]	El-Ridi *et al.* (1990)
Cairo	Abattoir	75	12 (16.0)	MAT (1:25)	Dubey *et al.* (1998)
Giza	Abattoir	160	36 (22.5)	MAT (1:25)	Shaapan *et al.* (2010)
NS	NS	32	11 (34.4)	ELISA[16]	Hassanain *et al.* (2013)
Assiut	Rural areas	55	11 (20.0), 41 (74.5)	LAT[2], ELISA[2]	Kuraa and Malek (2016)
Cairo, Giza, Kalubiya	NS	41	7 (17.1)	ELISA[17]	El Fadaly *et al.* (2017)

Table 17. Seroprevalence of *T. gondii* antibodies in pigs from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Cairo	Abattoir	142	31 (21.8)	IFA[5]	Maronpot and Botros (1972)
Alexandria	Abattoir	50	25 (50.0)	DT (1:8)	Rifaat *et al.* (1979)
Cairo	Abattoir	100	14 (14.0)	IHA	Ibrahim (1990)
Cairo	Abattoir	150	74 (49.3)	MAT	Ghattas (1999)[a]
Cairo	Farms	230	172 (74.7)	IFA[3]	Barakat *et al.* (2011)
NS	NS	230	185 (80.4)	ELISA[16]	Hassanian *et al.* (2013)
Cairo	Farms	180	102 (56.6)	MAT	El Moghazy *et al.* (2011)
			94 (52.2)	ELISA	
			77 (42.7)	IHA[4]	
			64 (35.5)	DT	
El Minia	Abattoir	100	None	IHA[1]	Abdel-Hafeez *et al.* (2015)[b]

[a]Viable *T. gondii* was isolated by both mice and cat bioassay.
[b]Forty (40.0%) had IgM antibodies.

oocysts infectivity was not proven. Sadek *et al.* (2015) found *T. gondii* tachyzoites, respectively, in five of 58 and six of 47 milk samples from sheep and goats; this is a very high proportion and the illustrations are not clear. In addition, Ahmed *et al.* (2014) found *T. gondii* DNA in four (8%) of 50 milk samples from goats. The presence of *T. gondii* DNA in milk does not mean the viability of the parasite.

Camels

In Egypt, camel meat is inexpensive and consumed mainly in some governorates such as Cairo, Kalubiya, Sharkia and Assiut. It seems that the published reports of toxoplasmosis in camels from Egypt do not reflect the true prevalence in Egyptian camels because most of the sampled camels were imported, particularly those slaughtered at the official abattoir in Cairo (El Basateen). Seroprevalence data are summarized in Table 14. Moreover, *T. gondii* oocysts were revealed from cats fed pooled meat samples from camels (Abdel-Gawad *et al.*, 1984). *Toxoplasma gondii* DNA was not found in 50 raw camel milk samples (Saad *et al.*, 2018).

Cattle and water buffaloes

Both cattle and buffaloes are considered resistant to *T. gondii* infection (Dubey, 2010). Apparently, they can clear the infection

Table 18. Seroprevalence of *T. gondii* antibodies in equines from Egypt

Species	Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
Donkeys	Menoufiya	Rural areas	121	79 (65.6)	ELISA[17]	El-Ghaysh (1998)
Horses	NS	Farms	420	[1]160 (38.1), [2]133 (31.7), [3]217 (51.7), 170 (40.5), 202 (48.1)	ELISA-LA[17], ELISA-LAunb[17], ELISA-Lab[17], IFAT[4], MAT (1:25)	Ghazy *et al.* (2007)[a]
Donkeys	Giza	Zoo abattoir	200	[1]89 (44.5), [2]104 (52.0), [3]72 (36.0), [4]78 (39.0)	MAT (1:25)	Shaapan and Khalil (2008)[b]
Draught horses	Cairo	Individual owners	100	25 (25.0)	ELISA[17]	Haridy *et al.* (2009)
Working donkeys	Cairo	Individual owners	100	45 (45.0)	ELISA[17]	Haridy *et al.* (2010)
Sport horses	Cairo	Main farm	240	125 (52.1), 122 (50.8), 94 (39.2)	LAT[3], MAT (1:25), ELISA[17]	Shaapan *et al.* (2012)
Donkeys	Dakahlia	NS	79	35 (44.3), 53 (67.1), 54 (68.4)	LAT[3], IHA[1], ELISA[16]	Younis *et al.* (2015)
Horses			54	27 (50.0), 39 (72.2), 39 (72.2)		
Donkeys	Giza	Individual owners	58	16 (27.6), 22 (37.9)	LAT[1], ELISA[15]	Fereig *et al.* (2016)
	Menoufiya		43	13 (30.2), 11 (25.6)		
	Matrouh		45	10 (22.2), 9 (20.0)		

[a]ELISA were carried out using [1]crude antigen (LA) prepared from local horse strain, and its purified immunogenetic fractions; [2]bound (LAb) and [3]unbound (LAunb) fractions.
[b]MAT was carried out using formalin-treated whole tachyzoites from different antigen; [1]RH strain, [2]local equine strain, [3]local camel strain and [4]local sheep strain.

Table 19. Seroprevalence of *T. gondii* antibodies in chickens from Egypt

Governorate	Source of sera	No. tested	No. positive (%)	Test	Reference
NS	NS	30	15 (50.0)	DT (1:8)	Rifaat *et al.* (1969)
Kalubiya	C Laying hens[a]	600	320 (53.3), 200 (33.3)	CFT (1:8), IHA[5]	Hassanain *et al.* (1997)
Giza	M	108	51 (47.4)	MAT (1:25)	El-Massry *et al.* (2000)
Menoufiya, Beheira	FR	121	49 (40.4)	MAT (1:5)	Dubey *et al.* (2003)
Assiut	C	90	10 (11.1)	MAT (1:50)	Deyab and Hassanein (2005)
	H	60	18 (30.0)		
Kafr ElSheikh	FR	84	32 (38.1)	IHA[1]	Harfoush and Tahoon (2010)
Different	FR	108	75 (69.5)	ELISA[16]	Barakat *et al.* (2012)
	C	331	227 (68.5)		
Beni Suef	FR	90	18 (20.0)	IHA[b]	Aboelhadid *et al.* (2013)
	SH	125	12 (9.6)		
Delta region	FR	97	16 (16.4)	ELISA[14]	Ibrahim *et al.* (2016)
	SH	207	18 (8.6)		
Cairo, Giza, kalubiya	FR	88	33 (37.5)	ELISA[17]	El Fadaly *et al.* (2017)

FR, free range chickens; H, house-bred chickens; M, market chickens; C, commercially farmed chickens; SH, slaughterhouse.
[a]Six hundred laying hens from three flocks (each of 12000 birds) suffered from drop in eggs production and high percent of embryonic mortalities.
[b]This test is wrongly identified in the report as MAT.

in their tissues and their role in transmission to humans is uncertain; however, some reports indicated the substantial role of beef in *T. gondii* transmission (Opsteegh *et al.*, 2011; Belluco *et al.*, 2018). Although antibodies to *T. gondii* have been reported in both species in Egypt (Tables 15 and 16), viable parasite has not been isolated from beef.

El-Tras and Tayel (2009) isolated viable *T. gondii* from tissues of two out of 30 buffaloes; however, it needs confirmation because there are no valid reports on the isolation of *T. gondii* from buffalo meat (Dubey, 2010), and the parasite was not found in tissues of three calves experimentally infected with 200 000 *T. gondii* oocysts (de Oliviera *et al.*, 2001). Moreover, *T. gondii* DNA was not found in 50 milk samples from cows (Ahmed *et al.*, 2014). The report of the presence of *T. gondii* DNA in 6% (3/50) of buffalo bull semen samples from Egypt needs confirmation (Abd El-Razik *et al.*, 2017).

Pigs

Due to religious concerns, pork is not popular in Egypt. Pigs are reared in small holdings mainly in Cairo and Kalubiya within a complete garbage feeding system including food remnants, rodents, and dead animals and birds. Thus, they are excellent indicators for

Table 20. Seroprevalence of *T. gondii* antibodies in rodents from Egypt

Species	Governorate	No. tested	No. positive (%)	Test	Reference
Rattus norvegicus	Cairo	100	34 (34.0)	DT	Rifaat *et al.* (1971)[a]
Rattus alexandrinus	Cairo	110	47 (42.7)	DT	Rifaat *et al.* (1973*d*)[a]
Acomys cahirinus	Different	101	36 (36.3)	DT (1:8)	Rifaat *et al.* (1976*a*)[a]
Rattus norvegicus	Port Said	104	32 (30.8)	IHA	Morsy *et al.* (1981)
Rattus norvegicus	Ismailia	150	21 (12.6)	IHA[5]	Morsy *et al.* (1982)
Rattus rattus		150	15 (10.0)		
Rattus norvegicus	Dakahlia	200	26 (13.0)	IHA[5]	El-Shazly *et al.* (1991)
Rattus rattus		228	20 (8.8)		
Mus musculus		87	None		
Acomys cahirinus		69	4 (5.8)		
Rattus norvegicus	Cairo, Giza	74	34 (45.9)	LAT[1]	El Fadaly *et al.* (2016)[b]
Rattus rattus		108	21 (19.4)		
Rattus frugivorus		96	13 (13.5)		
Rattus norvegicus	Giza	79	3 (3.8)	ELISA	Mikhail *et al.* (2017)
Rattus rattus		46	2 (4.3)		

[a]Viable *T. gondii* was isolated from brain pools by mice bioassay.
[b]Viable *T. gondii* was isolated by both mice and cat bioassay.

Table 21. Trials to isolate viable *T. gondii* from tissues of food animals and birds in Egypt by mice bioassay

Host	Governorate	Serological test	Samples	No. tested	No. positive (%)	References
Pig	Cairo	IFA	Heart, liver, kidney, brain	1	1 (100)	Botros *et al.* (1973)[a]
Pig	Cairo	MAT	Diaphragm	30	7 (23.3)	Ghattas (1999)[a]
Chicken	Beheira	MAT	Heart, brain	49	19 (38.7)	Dubey *et al.* (2003)[a]
Duck				3	1 (33.3)	
Buffalo	Middle Delta	ND	NS	30 fresh	2 (6.6)	El-Tras and Tayel (2009)
				30 frozen	None	
Sheep	Cairo	LAT[1]	Diaphragm	28	28 (100)	Hassanain *et al.* (2011)[a]
FR chicken	Different	ND	Hear, brain, breast	60	NC	El-Newishy *et al.* (2012)
C chicken				170		
Sheep	Cairo, Giza, Kalubiya	ELISA[17]	Diaphragm, thigh muscles	75	8 (10.7)	El Fadaly *et al.* (2017)[a]
Goat				49	4 (8.2)	
Cattle				16	None	
Buffalo				7	None	
Camel				4	2 (50.0)	
FR chicken				9	2 (22.2)	
Sheep	Cairo	OTRT	Diaphragm	34	15 (44.1)	Abd El-Razik *et al.* (2018)[a]
Goat				3	3 (100)	

ND, not done; NC, not clear; FR, free range; C, commercially farmed.
[a]The studied samples were from seropositive animals.

the spread of *T. gondii* infection. Reports on the seroprevalence of *T. gondii* in pigs from Egypt are given in Table 17.

Viable *T. gondii* was isolated from two seropositive pigs (Botros *et al.*, 1973) and seven (23.3%) of 30 pigs by mouse bioassay (Ghattas, 1999). Ghattas (1999) fed cats (*T. gondii*-seronegative) meats from seropositive pigs. Cats excreted *T. gondii*-like oocysts. The identity of the recovered oocysts was confirmed by oral inoculation in mice.

Equines

Generally, high *T. gondii* seroprevalences were reported in horses and donkeys from Egypt (Table 18). However, equine meat is not consumed by humans in Egypt. Anti-*T. gondii* antibodies were noted in seven out of 15 donkey milk samples (Haridy *et al.*, 2010).

Viable *T. gondii* has been isolated from tissues of 25 slaughtered donkeys at Giza zoo abattoir. *Toxoplasma gondii*-like

oocysts were found in nine of 25 cats fed donkey tissues (Younis *et al.*, 2015); however, the identity of these oocysts was not confirmed. Moreover, viable *T. gondii* were isolated from horses slaughtered at the same zoo (Shaapan and Ghazy, 2007). Donkeys and horses are slaughtered in the zoo for feeding of wild felids which can excrete *T. gondii* oocysts.

Chickens and other avian species

Chickens and ducks are widely consumed in Egypt due to their relatively cheap prices in comparison to red meats. Free range (FR) system of rearing birds is common in rural areas particularly in villages of Upper Egypt. FR birds are considered as a common source of human infection (Dubey, 2010). High seroprevalence was reported from FR chicken in Egypt, indicating high oocyst-environmental contamination (Table 19). Hassanain *et al.* (1997) stated a direct correlation between *T. gondii* seroprevalence and the decrease in egg production, although the seropositives were at low titres (⩽1:64) and the parasite isolation was not done. Viable *T. gondii* was isolated from both FR and commercially farmed chicken in Egypt (Table 21).

Little is known of toxoplasmosis in ducks. In Egypt, *T. gondii* seroprevalence ranges from 10.5 to 55% using different serological tests in different duck breeds (El-Massry *et al.*, 2000; Dubey *et al.*, 2003; Harfoush and Tahoon, 2010; AbouLaila *et al.*, 2011; Ibrahim *et al.*, 2018). Viable *T. gondii* was isolated from one of three seropositive FR ducks from Beheira governorate (Dubey *et al.*, 2003).

In other avian species, *T. gondii* seroprevalence was reported from 29.8% of 188 quails (Shaapan *et al.*, 2011), and 59.5% of 173 turkeys (El-Massry *et al.*, 2000) and 12.5% of 120 Ostriches (El-Madawy and Metawea, 2013). The latter found *T. gondii* DNA in the blood of nine ostriches. Additionally, *T. gondii* antibodies were reported from pigeons (Rifaat *et al.*, 1969; Ibrahim *et al.*, 2018).

Rabbits

Prevalence of *T. gondii* in rabbits from different Egyptian governorates is variable and ranges from 0 to 37.5% (Hilali *et al.*, 1991; Ibrahim *et al.*, 2009; Harfoush and Tahoon, 2010; Ashmawy *et al.*, 2011; Abou Elez *et al.*, 2017). Despite some reports placing the rabbit as a major source for human infection (Almeria *et al.*, 2004), we think that the role of rabbits is not of such importance because 90% of rabbits in Egypt are fed commercial pellets in small farms and kept in hutches or cages, which limit the chances of oocyst ingestion.

Rodents

Rodents are important for *T. gondii* epidemiology because they serve as a source of infection for cats (Dubey, 2010). Reports on the seroprevalence of *T. gondii* in different species of rodents from Egypt are given in Table 20. Viable *T. gondii* was isolated by mouse bioassay (Rifaat *et al.*, 1971, 1973*d*, 1976*a*) and/or cat bioassay (El Fadaly *et al.*, 2016).

Isolation of viable T. gondii *from food animals*

Viable *T. gondii* was isolated from tissues of different food animals and birds in Egypt by mouse bioassay (Table 21). Cat bioassay was also used in some studies, and *T. gondii*-like oocysts were excreted from cats fed pooled meat samples. However, no further definitive procedures for theses oocysts were done in many studies (Abdel-Gawad *et al.*, 1984; El-Massry *et al.*, 1990; Hassanain *et al.*, 2011).

Perspective

There are many reports on toxoplasmosis in animals and humans from Egypt, but there is no statistically-valid prevalence study on the national level. Little is known concerning clinical toxoplasmosis in humans or livestock in Egypt. Toxoplasmosis is usually considered by the physicians in Egypt as a cause of abortions and complications in pregnant women; however, the published studies are not well-structured and lack definitive diagnosis. There is a great need to establish a well-planned study concerning congenital toxoplasmosis in Egypt. Reports on toxoplasmosis in animals were based on commercial kits with unconfirmed validity. A large-scale study is needed employing validated serological methods and includes procedures for isolation of the parasite to critically evaluate the role of different food animals from Egypt in the transmission of *T. gondii* to humans.

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