

Flour and Cereal Grains – Surveys for Foodborne Pathogens: Tables and References

To repost or cite, please use the following citation: Harris, L. J., and S. Yada. 2022. Prevalence and levels of foodborne pathogens on flour and cereal grain products [Tables and references]. *In* Flour & Cereal Grains – Surveys for foodborne pathogens. Available at: <https://ucfoodsafety.ucdavis.edu/low-moisture-foods/lmf-information-uc>.

Table 1. Prevalence of *Salmonella* on naturally contaminated wheat, wheat flour, and cereal grain products

Table 2. Levels of *Salmonella* in positive samples of naturally contaminated wheat, wheat flour, and cereal grain products

Table 3. Prevalence of other foodborne pathogens (non-*Salmonella*) or generic *E. coli* on naturally contaminated wheat, wheat flour, and cereal grain products

Table 1. Prevalence of *Salmonella* on naturally contaminated wheat, flour, and cereal grain products

Product	Where collected	Sample size (g) ^a	No. of samples tested (n)	No. positive for <i>Salmonella</i>	Percent positive (if n>50)	<i>Salmonella</i> serotype	References
WHEAT							
WHEAT GRAINS							
1977 samples	Retail, US	375	40	0	0		Andrews et al., 1979
1997–1999 samples	Flour mill receiving – pre-conditioning, Australia	25	58	0	0		Berghofer et al., 2003
1997–1999 samples	Flour mill receiving – post-conditioning grain + grist, Australia	25	187 (90 grain + 97 grist)	2	1.1	Chester, Hvittingfoss	Berghofer et al., 2003
1997–1999 samples							
2006–2007 samples	Flour mill receiving, Australia	100	50	1	2.0	Give	Eglezos, 2010
2012–2013 samples	Combine harvesters, US	25	54	0	0		Sabillón et al., 2016
2012–2014 samples	Grain trailers/trucks, US	375	3,891	48	1.23		Myoda et al., 2019
Hard red spring	“	“	653	2	0.31		“
Hard red winter	“	“	1,353	21	1.55		“
Soft red winter early	“	“	1,168	12	1.03		“
Soft red winter late	“	“	717	13	1.81		“
WHEAT FLOUR							
1977 samples	Retail, US	375	60	0	0		Andrews et al., 1979
1984–1991 samples	Flour mills, North America	(not stated)	1,170	4	0.34		Sperber, 2003

L. J. Harris and S. Yada. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 9/30/2022.

Product	Where collected	Sample size (g) ^a	No. of samples tested (n)	No. positive for <i>Salmonella</i>	Percent positive (if n>50)	<i>Salmonella</i> serotype	References
1989 samples	Flour mills, North America	25	3,040	40	1.32		Richter et al., 1993
1989 samples (3 types, no durum)	Flour mills, North America	25	2,224	38	1.71		Richter et al., 1993
1989 samples (durum)	Flour mills, North America	25	816	2	0.25		Richter et al., 1993
1997–1999 samples	Flour mills, Australia	25	71	0	0		Berghofer et al., 2003
2003–2005 samples	Flour mills, North America	25, 100, or 375	4,358	6	0.14		Sperber et al., 2007
2003–2005 samples (durum wheat)	Flour mills, North America	25, 100, or 375	180	0	0		Sperber et al., 2007
2003–2005 samples (whole wheat)	Flour mills, North America	25, 100, or 375	286	0	0		Sperber et al., 2007
2006–2007 samples	Flour mills, Australia	100	150	0	0 (<0.7)		Eglezos, 2010
2018–2019 samples	Retail, Canada	125	347	0	0		Zhang et al., 2020
WHEAT BRAN							
1997–1999 samples	Flour mills, Australia	25	54	0	0		Berghofer et al., 2003
WHEAT GERM							
1997–1999 samples	Flour mills, Australia	25	42	0			Berghofer et al., 2003
OTHER FLOURS							
CORN/MAIZE FLOUR							
2003–2005 samples	Flour mills, North America	25, 50, 150	1,772	0	0		Sperber et al., 2007
2010–2015 samples	Retail, Northern Italy	25	23	0			Losio et al., 2017
OAT FLOUR							
2001–2005 samples	Flour mills, North America	25	714	0	0		Sperber et al., 2007
RYE FLOUR							
1977 samples	Retail, US	375	60	1	1.66	Molade	Andrews et al., 1979

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Product	Where collected	Sample size (g) ^a	No. of samples tested (<i>n</i>)	No. positive for <i>Salmonella</i>	Percent positive (if <i>n</i> >50)	<i>Salmonella</i> serotype	References
CEREAL PRODUCTS							
RICE - BROWN							
1977 samples	Retail, US	375	60	1	1.66	Anatum	Andrews et al.,1979

^a Sample size is the size of the sample that was enriched and used to determine the prevalence (percent positive samples).

^b Buckwheat is not a cereal or grain.

Table 2. Levels of *Salmonella* in positive samples of naturally contaminated wheat, flour, and cereal grain products

Product	Where collected	Sample size (g)	<i>Salmonella</i> levels (MPN/g)	References
WHEAT				
2012–2014 samples	Grain trailers/trucks, US	375 x 1 and 3 each: 100, 10, 1, 0.1	3,891 samples: 0.110 ± 0.448	Myoda et al., 2019
Hard red spring	“	”	653 samples: 0.003	“
Hard red winter	“	“	1,353 samples: 0.181	“
Soft red winter early	“	“	1,168 samples: 0.002	“
Soft red winter late	“	“	717 samples: 0.011	“

Table 3. Prevalence of other foodborne pathogens (non-*Salmonella*) or generic *E. coli* on naturally contaminated wheat, flour, and cereal grain products

Product	Where collected	Sample size (g) ^a	No. of samples tested (n)	Assay	References
WHEAT					
WHEAT GRAINS					
1997–1999 samples	Flour mill receiving – pre-conditioning, Australia	25	58	<i>Bacillus cereus</i> (47 positive [81%], 0.1–10 MPN/g) Generic <i>E. coli</i> (none positive)	Berghofer et al., 2003
1997–1999 samples	Flour mill receiving – post-conditioning, Australia	25	90	<i>Bacillus cereus</i> (58 positive [64%], 0.1–10 MPN/g) Generic <i>E. coli</i> (13 positive [14%], 1–100 MPN/g)	Berghofer et al., 2003
2006–2007 samples	Flour mill receiving, Australia	100	50	<i>Bacillus cereus</i> (2 positive [4%], mean 2.1 log CFU/g) Generic <i>E. coli</i> (1 positive [2%], 0.6 log CFU/g)	Eglezos, 2010
2012–2013	Combine harvester, US	25	54	<i>E. coli</i> O157:H7 (none positive)	Sabillón et al., 2016
2012–2014 samples	Grain trailers/trucks, US	375 x 1 and 3 each: 100, 10, 1, 0.1	3,891	EHEC (17 positive [0.44%] at 0.039 ± 0.175 MPN/g) <i>Listeria</i> spp. (1 positive [0.08%] at 0.020 MPN/g) <i>E. coli</i> O157, <i>L. monocytogenes</i> (none positive)	Myoda et al., 2019
WHEAT FLOUR					
1989 samples	Flour mills, North America	(not stated)	3,350	Generic <i>E. coli</i> (429 positive [12.8%])	Richter et al., 1993
1989 samples (3 types, no durum)	Flour mills, North America	(not stated)	2,366	Generic <i>E. coli</i> (262 positive [11.1%])	Richter et al., 1993
1989 samples (durum)	Flour mills, North America	(not stated)	984	Generic <i>E. coli</i> (167 positive [17%])	Richter et al., 1993
1997–1999 samples	Flour mills, Australia	25	71	<i>Bacillus cereus</i> (66 positive [93%], 0.1–10 MPN/g) Generic <i>E. coli</i> (1 positive [1.4%] at 9 MPN/g)	Berghofer et al., 2003
2003–2005 samples	Flour mills, North America	25, 100, or 375	2,921	Generic <i>E. coli</i> (mean 0.7, max 3.0 log CFU/g)	Sperber et al., 2007
2003–2005 samples (durum wheat)	Flour mills, North America	25, 100, or 375	268	Generic <i>E. coli</i> (mean 0.18, max 2.66 log CFU/g)	Sperber et al., 2007
2003–2005 samples (whole wheat)	Flour mills, North America	25, 100, or 375	410	Generic <i>E. coli</i> (mean 0.16, max 2.49 log CFU/g)	Sperber et al., 2007
2006–2007 samples	Flour mills, Australia	100	300	<i>Bacillus cereus</i> (none positive, LOD 2 log CFU/g) Generic <i>E. coli</i> (2 positive [0.7%], mean 0.8 CFU/g)	Eglezos, 2010
2014–2017 samples	Flour mills, Germany	25	37	STEC (7 positive [18.9%])	Mäde et al., 2017

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Product	Where collected	Sample size (g) ^a	No. of samples tested (n)	Assay	References
2017-2018 samples	Retail, Switzerland	25	52	STEC (9 positive [17.3%])	Boss and Hummerjohann, 2019
2018 samples	Retail, Switzerland	10	41	<i>Bacillus cereus sensu lato</i> (37 positive [90%])	Kindle et al., 2019
2018–2019 samples	Retail, Canada	125 (pathogens) 10 (generic <i>E. coli</i>)	347	<i>L. monocytogenes</i> (2 positive [0.6%] at <0.7 log CFU/g) <i>E. coli</i> O157:H7 (none positive) Non-O157 STEC (6 positive [1.7%]) Generic <i>E. coli</i> (2 positive [0.6%] at ≥0.5–<1 log CFU/g)	Zhang et al., 2021
WHEAT BRAN					
1997–1999 samples	Flour mills, Australia	25	54	<i>Bacillus cereus</i> (51 positive [94%], 0.1–100 MPN/g) Generic <i>E. coli</i> (2 positive [4%], 1–10 MPN/g)	Berghofer et al., 2003
WHEAT GERM					
1997–1999 samples	Flour mills, Australia	25	43	<i>Bacillus cereus</i> (27 positive [64%], 0.1–10 MPN/g) Generic <i>E. coli</i> (5 positive [11%], 1 MPN/g)	Berghofer et al., 2003
OTHER FLOURS					
CORN/MAIZE FLOUR					
2010–2015 samples	Retail, Italy	25	23	<i>Bacillus cereus</i> [4.3%] at <1–<2 log CFU/g	Losio et al., 2017
RYE FLOUR					
2014–2017 samples	Flour mills, Germany	25	14	STEC (4 positive [28.6%])	Mäde et al., 2017
2018 samples	Retail, Switzerland	10	5	<i>Bacillus cereus sensu lato</i> (4 positive [80%])	Kindle et al., 2019

^a Sample size is the size of the sample that was enriched and used to determine the prevalence (percent positive samples).

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