**Analyzing multidrug resistance patterns across the food supply chain using association rule mining**

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**1. Introduction**

**2. Methods**

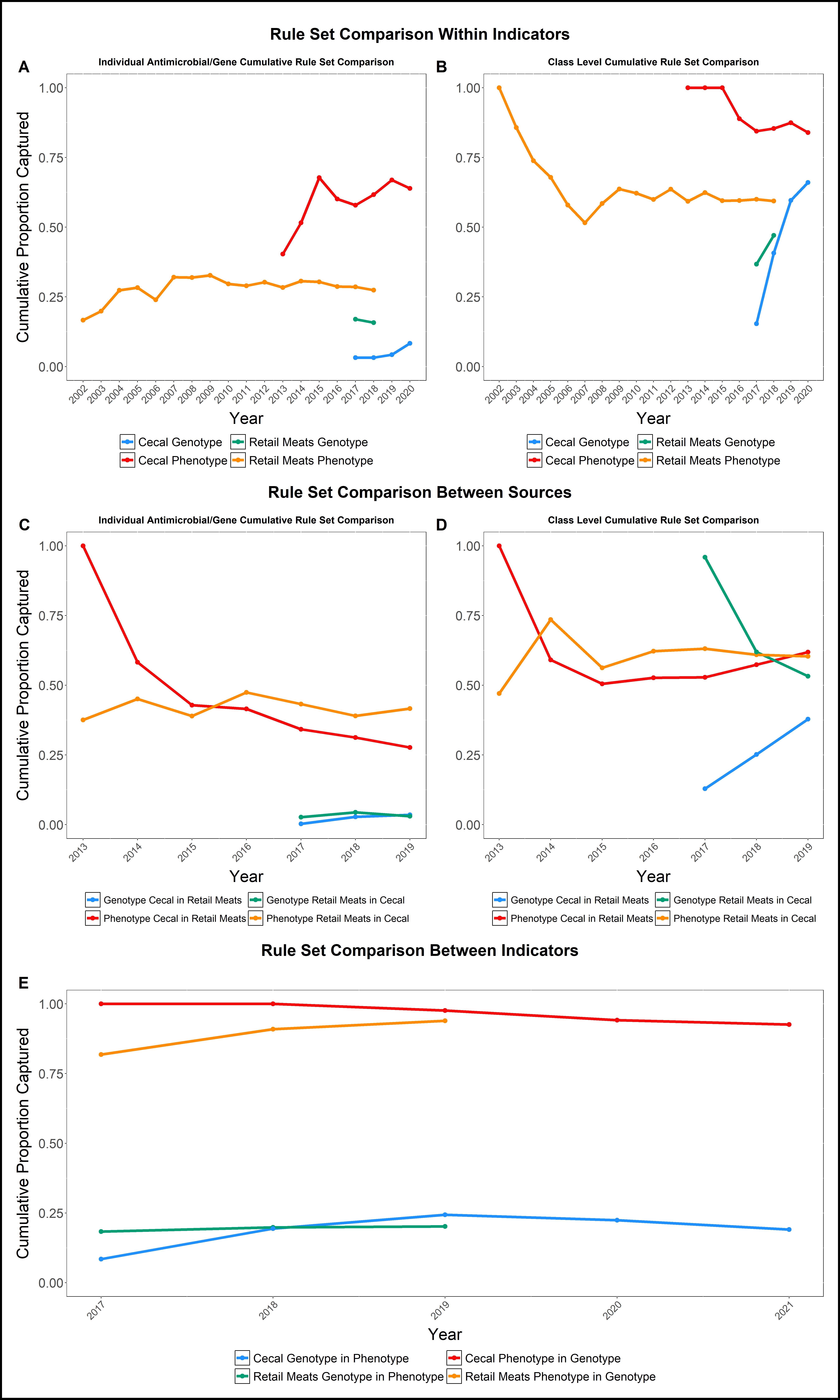
**3 Resul**

3.1 Prevalence Descriptives

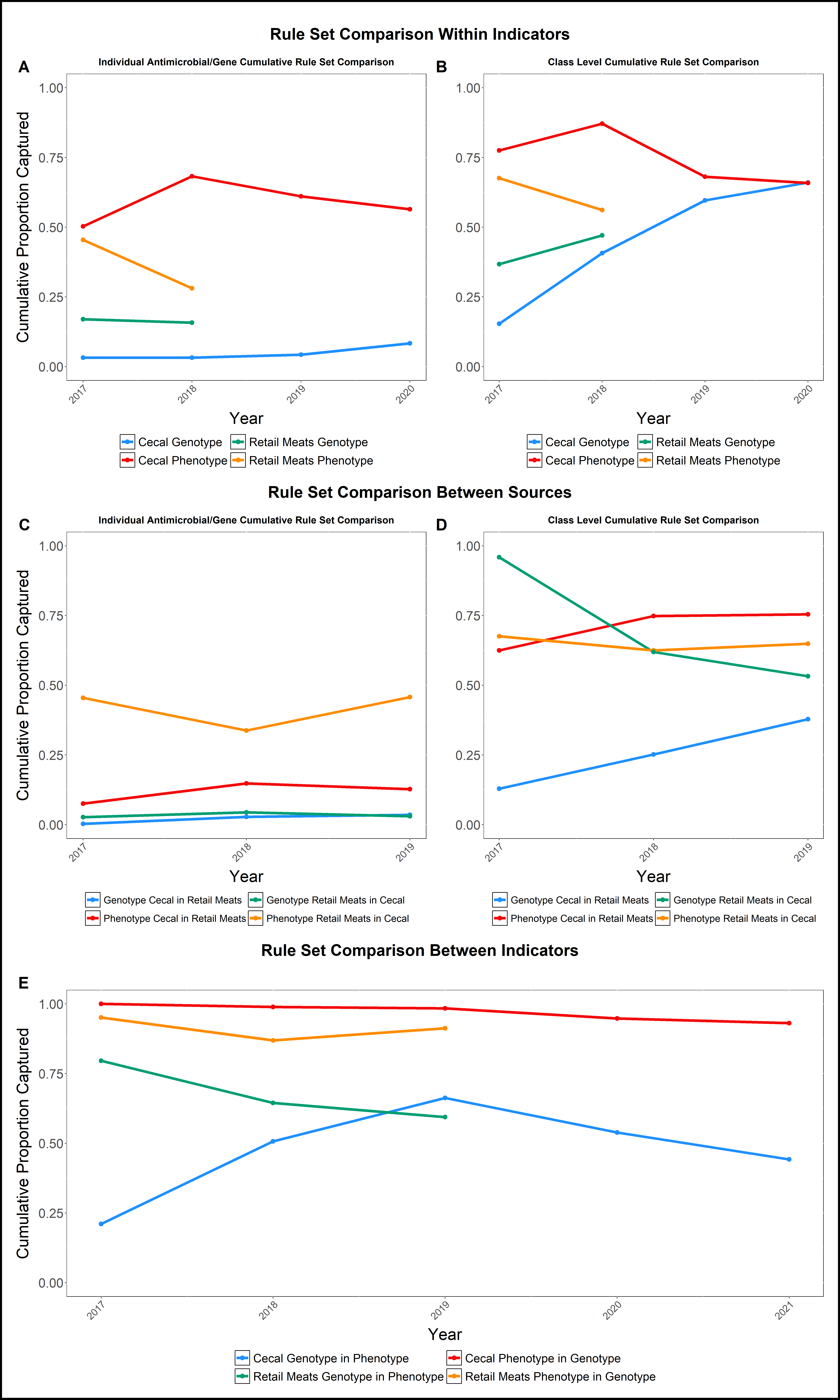
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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Antimicrobial Level Phenotypic Resistance Prevalence | | | | | | | | | | | | | | | | |
|  | Year | N | AMC | AMP | AXO | CHL | CIP | COT | FIS | FOX | GEN | NAL | TET | AZI | MER | SMX |
| Retail Meats | 2002 | 295 | 2.03 | 6.1 | 0 | 1.02 | 0 | 0.68 | NA | 0 | 0.34 | 0 | 30.85 | NA | NA | 10.17 |
| 2003 | 311 | 2.25 | 5.14 | 0.32 | 2.25 | 0 | 0.32 | NA | 0 | 0.96 | 0.96 | 25.08 | NA | NA | 10.29 |
| 2004 | 338 | 3.85 | 5.33 | 1.48 | 3.55 | 0 | 0.59 | 13.02 | 1.18 | 0.59 | 1.48 | 22.78 | NA | NA | NA |
| 2005 | 316 | 1.27 | 3.48 | 1.9 | 1.58 | 0.32 | 0.63 | 6.96 | 0.95 | 0 | 1.27 | 16.46 | NA | NA | NA |
| 2006 | 295 | 2.37 | 9.15 | 1.69 | 1.36 | 0 | 1.36 | 12.54 | 2.03 | 4.07 | 0.68 | 25.42 | NA | NA | NA |
| 2007 | 256 | 0.78 | 6.64 | 0.78 | 3.91 | 0 | 1.17 | 9.38 | 0.78 | 0 | 0.39 | 21.88 | NA | NA | NA |
| 2008 | 250 | 2.4 | 6.4 | 1.6 | 0.8 | 0 | 2 | 11.6 | 2.4 | 2 | 0.4 | 24 | NA | NA | NA |
| 2009 | 247 | 1.62 | 4.88 | 0.81 | 2.43 | 0 | 2.02 | 7.69 | 1.62 | 0.81 | 0.4 | 18.62 | NA | NA | NA |
| 2010 | 269 | 1.12 | 4.83 | 1.12 | 2.6 | 0 | 0.74 | 12.64 | 1.12 | 0.37 | 0 | 22.68 | NA | NA | NA |
| 2011 | 215 | 0.47 | 3.72 | 0.47 | 1.4 | 0 | 2.33 | 7.91 | 0.47 | 0.47 | 0 | 17.67 | 0 | NA | NA |
| 2012 | 271 | 1.48 | 2.58 | 0 | 1.11 | 0 | 0.37 | 7.38 | 1.85 | 0.74 | 1.48 | 22.14 | 0 | NA | NA |
| 2013 | 227 | 1.76 | 4.85 | 2.2 | 3.96 | 0 | 1.76 | 7.93 | 1.32 | 0 | 0.44 | 22.47 | 0 | NA | NA |
| 2014 | 205 | 0.49 | 4.39 | 0.49 | 0.49 | 0 | 0.98 | 7.8 | 0.98 | 0.49 | 0 | 21.46 | 0 | NA | NA |
| 2015 | 227 | 0.44 | 2.64 | 0.44 | 1.32 | 0 | 1.32 | 7.49 | 0.44 | 0.44 | 0.44 | 18.5 | 0 | NA | NA |
| 2016 | 174 | 1.15 | 6.32 | 0.57 | 5.17 | 0 | 1.15 | 9.77 | 1.15 | 0.57 | 0 | 23.56 | 0 | 0 | NA |
| 2017 | 271 | 0.37 | 6.27 | 0.37 | 2.58 | 0 | 1.11 | 6.27 | 0 | 0 | 1.85 | 21.77 | 0 | 0 | NA |
| 2018 | 133 | 0.75 | 3.76 | 0 | 3.76 | 0.75 | 0.75 | 10.53 | 0 | 0 | 1.5 | 20.3 | 0 | 0 | NA |
| 2019 | 286 | 0 | 2.1 | 0 | 2.45 | 0 | 0.7 | 6.64 | 0 | 0.7 | 0.7 | 19.58 | 0 | 0 | NA |
| Cecal | 2013 | 549 | 0.73 | 3.46 | 0.73 | 0 | 3.1 | 0 | 0 | 7.47 | 0.55 | 0.18 | 0 | 21.68 | NA | NA |
| 2014 | 503 | 0.99 | 4.97 | 0.99 | 0 | 3.78 | 0.2 | 0.8 | 11.53 | 0.8 | 0.4 | 0.4 | 31.81 | NA | NA |
| 2015 | 891 | 1.46 | 7.18 | 1.57 | 0 | 5.5 | 1.12 | 1.57 | 14.37 | 1.35 | 0.79 | 2.02 | 33.11 | NA | NA |
| 2016 | 1188 | 1.26 | 6.06 | 1.18 | 0.17 | 5.81 | 0.25 | 0.59 | 13.55 | 1.18 | 0 | 0.93 | 32.41 | 0 | NA |
| 2017 | 1382 | 0.87 | 5.79 | 0.94 | 0.22 | 5.14 | 0 | 1.16 | 13.89 | 0.72 | 0.07 | 0.65 | 32.49 | 0 | NA |
| 2018 | 1444 | 0.97 | 6.44 | 0.97 | 0 | 7.13 | 0.28 | 1.25 | 13.92 | 1.04 | 0.35 | 1.59 | 31.65 | 0 | NA |
| 2019 | 1181 | 0.59 | 5.33 | 0.85 | 0.08 | 5.76 | 0.17 | 1.02 | 11.77 | 0.59 | 0.25 | 1.35 | 27.35 | 0 | NA |
| 2020 | 779 | 4.24 | 16.82 | 5.01 | 0.77 | 10.65 | 1.03 | 8.1 | 19.77 | 4.36 | 1.16 | 1.54 | 34.58 | 0 | NA |
| 2021 | 429 | 1.86 | 9.56 | 3.96 | 0.93 | 8.16 | 0.47 | 3.96 | 15.85 | 2.1 | 1.4 | 1.4 | 31 | 0 | NA |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Class Level Phenotypic Resistance Prevalence | | | | | | | | | |
|  | Year | N | Phenicol | Aminoglycoside | Tetracycline | Macrolide | Beta lactam | Folate-pathway-inhibitor | Quinolone |
| Retail Meats | 2002 | 295 | 1.02 | 0.34 | 30.85 | NA | 7.12 | 10.17 | 0 |
| 2003 | 311 | 2.25 | 0.96 | 25.08 | NA | 6.11 | 10.29 | 0.96 |
| 2004 | 338 | 3.55 | 0.59 | 22.78 | NA | 6.8 | 13.02 | 1.48 |
| 2005 | 316 | 1.58 | 0 | 16.46 | NA | 4.75 | 6.96 | 1.58 |
| 2006 | 295 | 1.36 | 4.07 | 25.42 | NA | 9.15 | 12.54 | 0.68 |
| 2007 | 256 | 3.91 | 0 | 21.88 | NA | 6.64 | 9.38 | 0.39 |
| 2008 | 250 | 0.8 | 2 | 24 | NA | 6.4 | 12 | 0.4 |
| 2009 | 247 | 2.43 | 0.81 | 18.62 | NA | 4.86 | 7.69 | 0.4 |
| 2010 | 269 | 2.6 | 0.37 | 22.68 | NA | 4.83 | 12.64 | 0 |
| 2011 | 215 | 1.4 | 0.47 | 17.67 | 0 | 3.72 | 7.91 | 0 |
| 2012 | 271 | 1.11 | 0.74 | 22.14 | 0 | 4.06 | 7.38 | 1.48 |
| 2013 | 227 | 3.96 | 0 | 22.47 | 0 | 4.85 | 7.93 | 0.44 |
| 2014 | 205 | 0.49 | 0.49 | 21.46 | 0 | 4.88 | 7.8 | 0 |
| 2015 | 227 | 1.32 | 0.44 | 18.5 | 0 | 2.64 | 7.49 | 0.44 |
| 2016 | 174 | 5.17 | 0.57 | 23.56 | 0 | 6.32 | 9.77 | 0 |
| 2017 | 271 | 2.58 | 0 | 21.77 | 0 | 6.27 | 6.27 | 1.85 |
| 2018 | 133 | 3.76 | 0 | 20.3 | 0 | 3.76 | 10.53 | 1.5 |
| 2019 | 286 | 2.45 | 0.7 | 19.58 | 0 | 2.1 | 6.64 | 0.7 |
| Cecal | 2013 | 549 | 3.1 | 0.18 | 21.68 | 0 | 3.46 | 7.47 | 0 |
| 2014 | 503 | 3.78 | 0.4 | 31.81 | 0 | 5.37 | 11.73 | 0.4 |
| 2015 | 891 | 5.5 | 0.79 | 33.11 | 0 | 7.3 | 14.37 | 2.02 |
| 2016 | 1188 | 5.81 | 0 | 32.41 | 0.17 | 6.14 | 13.55 | 0.93 |
| 2017 | 1382 | 5.14 | 0.07 | 32.49 | 0.22 | 5.86 | 13.89 | 0.65 |
| 2018 | 1444 | 7.13 | 0.35 | 31.65 | 0 | 6.58 | 13.92 | 1.59 |
| 2019 | 1181 | 5.76 | 0.25 | 27.35 | 0.08 | 5.42 | 11.77 | 1.35 |
| 2020 | 779 | 10.65 | 1.16 | 34.58 | 0.77 | 17.07 | 19.77 | 1.54 |
| 2021 | 429 | 8.16 | 1.4 | 31 | 0.93 | 9.79 | 15.85 | 1.4 |

3.2 Rule Set Comparison

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**Figure 1: rule set comparison for the full range of data (excludes streptomycin).**

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**Figure 2: rule set comparison for data from 2017 onward (includes streptomycin).**

3.3 Network Graph Analysis

3.4 Tabulation Comparison

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Retail Meats | | | Cecal | | |
| Resistance Pattern | Frequency | Recovered Resistance Pattern | Resistance Pattern | Frequency | Recovered Resistance Pattern |
| TET | 838 | \_ | TET | 1337 | \_ |
| CHL; TET | 67 | Yes | FIS; TET | 506 | Yes |
| COT; TET | 18 | Yes | AMP; CHL; FIS; TET | 177 | Yes |
| GEN; TET | 16 | Yes | CHL; FIS; TET | 139 | Yes |
| NAL | 12 | \_ | AMP; TET | 100 | Yes |
| AMC | 10 | \_ | AMP | 33 | \_ |
| COT | 8 | \_ | AMP; FIS; TET | 29 | Yes |
| AMC; AXO; FOX | 7 | Yes | AMP; CHL; COT; FIS; TET | 27 | Yes |
| AMC; TET | 7 | Yes | CHL; FIS; NAL; TET | 19 | Yes |
| NAL; TET | 7 | Yes | AMC; AMP; AXO; FOX | 17 | Yes |

**4 Discussion**

**5 Conclusions**