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Is the low pH of infant and toddler foods a concern?

To the editor

The acidic environment within the oesophageal lumen has been linked to oesophageal inflammation and barrier injury, relating to oesophageal diseases such as EoE and GORD.(1, 2) Furthermore, Epithelial injury and dysfunction(3-5) has recently become a focus of allergic disease of the skin, airways and oesophagus[11-14]. The incidence of food allergy is increasing(6) in both the western and eastern world, and new allergic enteropathic conditions such as eosinophilic esophagitis and GORD. (7, 8)

Diet histories taken at an allergy clinic showed an observed increasing trend in the use of commercial infant/toddler foods by parents of infant and toddlers diagnosed with eosinophilic esophagitis (EoE) and gastro-oesophageal reflux disease (GORD). Parents reported to use these products up to 6 times per day, mainly due to convenience. We further base our observation of increased intake of infant foods on the basis of increased infant food sales, particularly pouches, of which the majority of these products (over 60%) contains fruit. (9-11) Reports also indicated an increase in the incidence of EoE and GORD alongside an increase in the sales of infant/toddler foods.(12-14)

A pH of less than 4 within the oesophagus, as well as environmental factors, may cause epithelial injury.(1, 5, 15) Oesophageal injury is more likely with frequent reflux and this relates both to the pH and the stability and activity of pepsin. Pepsin, once attached to epithelium, has long-term stability and does not start to degrade unless the pH is higher than 7.5. A bolus of reflux is normally neutralised by ingested saliva that protects both the oesophagus and teeth.(16) Chewing is the main stimulus for the production of saliva.(17) Chewing is therefore a crucial a mechanism by which saliva can help buffer acidic foods. Pouch and pureed foods do not encourage chewing, in fact most of these foods do not require chewing at all. This can reduce

satiety as chewing induces satiety. A recent study indicated that particle size in yogurt increases chewing and reduces food intake during a meal.(18) The lack of chewing may also negatively affect jaw development, which appears to by-passed by foods that are in pouch packs.(19) Chewing foods has been shown to activate chewing muscles and also affect saliva production.(20) Salivation and its neutralizing effect on pH is also impaired. Adults studies indicate that that salivation depends mainly on mastication/chewing.(21) In addition, they may have a low pH due to increased used of fruits and fruit juices to enable pasteurization opposed to sterilization.(19) Pasteurization (63° C - 72° C) needs a lower pH to kill pathogens than sterilization (121°C -132°C). They tend to be sweet and may provide a continued high-contact acid environment without the normal physiological equipoise to counter acidification (figure 1). Approximately 60% of pouches contain fruit opposed to 20% of jars.(11)The aim of our study was therefore to perform a pilot study to determine the pH profile of commonly consumed infant/toddler foods.

We measured the pH of foods that form part of the infant and toddler diet in Australia, however these foods are available on an international level.(10) We measured the pH of commercially available infant/toddler foods; pouches, infant/toddler jars and infant formula and compared to home-made foods (tables A-E). We considered a pH of <4 to be markedly acidic (for reference the pH of coke = 2.64 and cow's milk 5.59) and a pH >4, but <5 to be mildly acidic. The average pH for each item is shown in ascending order within the tables in the supplementary material. In total 107 foods, were selected for pH testing chosen at random using online shopping with a major supermarket. The average pH for each item is shown in ascending order within the tables in the supplementary material. We selected 60 commercially packaged infant and toddler food products; 25 predominantly contained fruit and/or fruit juice (>75% composition), 3 predominately contained vegetables (>75% composition), 9 were combination fruit and/or vegetable pouches, 19 products were classified as a meal (a combination of fruit and/or vegetables with meat, dairy, grains and/or pasta) and the remaining 4 products were dairy based (>25% composition of milk/cream). We also selected 4 yoghurts and 37 fresh produce items commonly consumed by infants and toddlers and 6 canned items commonly eaten by infants and toddlers. A two-point manual calibration probes with 0.01pH resolution and calibrated with PH buffer solutions of pH 4 and PH 7 was used for pH analysis. *Hanna Instruments - pH Checker Series. HI98103. 584, Park East Drive, Woonsocet, RI02895, USA.*

We recorded the pH of 37 (See supplementary table A) commercial fruit, vegetable and fruit-vegetable combination infant foods. The recorded pH ranged from 3.38 to 5.67. Of the 37 items,

28 were found to be acidic and 6 were mildly acidic. The markedly acidic (pH<4) food items contained a minimum composition of 46% fruit, while the mildly acid food items contained a minimum composition of 30% fruit with no more than 40% vegetable or 11.5% dairy. Apple was an ingredient in 19 of the 28 acidic items identified. Apple was closely followed by pear and berries, which were both found in 11 of the 28 products.

Commercial infant foods classified as a 'meal (n=19) (supplementary table B) have two definitions. The first definition requires a product to contain fruit with at least one of the following: vegetable, meat, grain, pasta or dairy (milk, cream or cheese). Using this definition, 6 meal items were identified, and the recorded pH ranged from 4.00 to 5.49, with 4 out of the 6 items classed as mildly acid. The second definition of an infant 'meal' requires a product to contain vegetables, with no fruit and at least one of the following: meat, grain, pasta or dairy. Without fruit, the recorded pH for the remaining 13 meal items ranged from 5.22 to 6.01 (minimally acidic). We analysed 4 commercial dairy based infant food items (supplementary table C) and their pH ranged from 3.76 to 6.30. The only acidic dairy based infant item contained 62% fruit. The pH of the non-infant specific plain and fruit flavoured yoghurts (supplementary table D) ranged from 4.29 to 4.65 and are classed as mildly acidic. Comparing non-commercial, home prepared infant food (n=37) (supplementary table E), we found that 7 foods were markedly acid, 7 foods were mildly acidic and 23 were non-acidic. Canned foods often consumed by toddlers had a pH range of 4.78 – 5.77 (n=7) (table F).

We have compared home-cooked foods to comparable foods in pouches and found that the pH of home-cooked food was higher in 10/12 foods (table G). The foods with added apple and/or vitamin C/citric acid all had lower pH than the home-cooked alternative (n=5). This was also true for the baby dessert with added vitamin C compared to yoghurt, though both of these foods were classified as mildly acid.

Supplementary tables F-I contain 33 food items traditionally consumed by adults but also consumed by children. Apple was the most acidic food item recorded across the 106 items tested, excluding condiments: lime juice, vinegar and raspberry jam, beverages: Coke and Remedy Apple Kombucha, and citric acid, all of which had a pH below 3. Passionfruit was also classed as acidic, with tomato and banana classed as mildly acidic.

In conclusion, epithelial barrier integrity and inflammation appears to be an important factor in the etiology of allergic diseases, which are dramatically increasing in the last few decades alongside an increase in sales of commercial infant/toddler foods. The results from our study questions if the low pH found in commercial baby foods, particularly those with fruit or citric acid added may be driving the increase in diseases related to epithelial injury. (4) The majority of infant/toddler

foods containing fruit and vegetables, have a low pH. Some of the infant/toddler meals, particularly those with fruit, vitamin and/or citric acid added have a low pH. We hypothesize that this may contribute to epithelial injury. We are not able to prove any causal relationship at this stage, but we offer novel data that may prompt further research. A further important factor is that chewing can induce satiety, the production of digestive enzymes including those in saliva and is important for jaw development, which appears to be by-passed by foods that are in pouch packs. We question if frequent consumption of commercial infant and toddler foods, with added acidic fruit and/or citric acid, negatively affects esophageal epithelium integrity and whether their widespread availability in a form requiring no or limited chewing, may be a further contributing factor.

Ethics and Trial Registration. This study did not require ethics involvement or trial registry.

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Author contributions:
All authors contributed to the paper. TK performed the analysis of the infant/toddler food samples. CV finalized and submitted the paper. VS and PS developed the initial concept of the paper. Dr Velencia Soutter was an active author in this paper, but she died on September 24th, 2019 after a short battle with cancer. All authors wish for her to be included in the paper and there has not been any data changes since her death.

Declarations of interest:

Dr. Venter reports personal fees from Danone, personal fees from Reckitt Benckiser, personal fees from Abbott Laboratories, personal fees from DBV technologies, outside of the submitted work. Dr. Smith reports fees from Nestle Nutrition Institute, personal fees from Bayer, outside of the submitted work. The other authors have no conflicts to declare.

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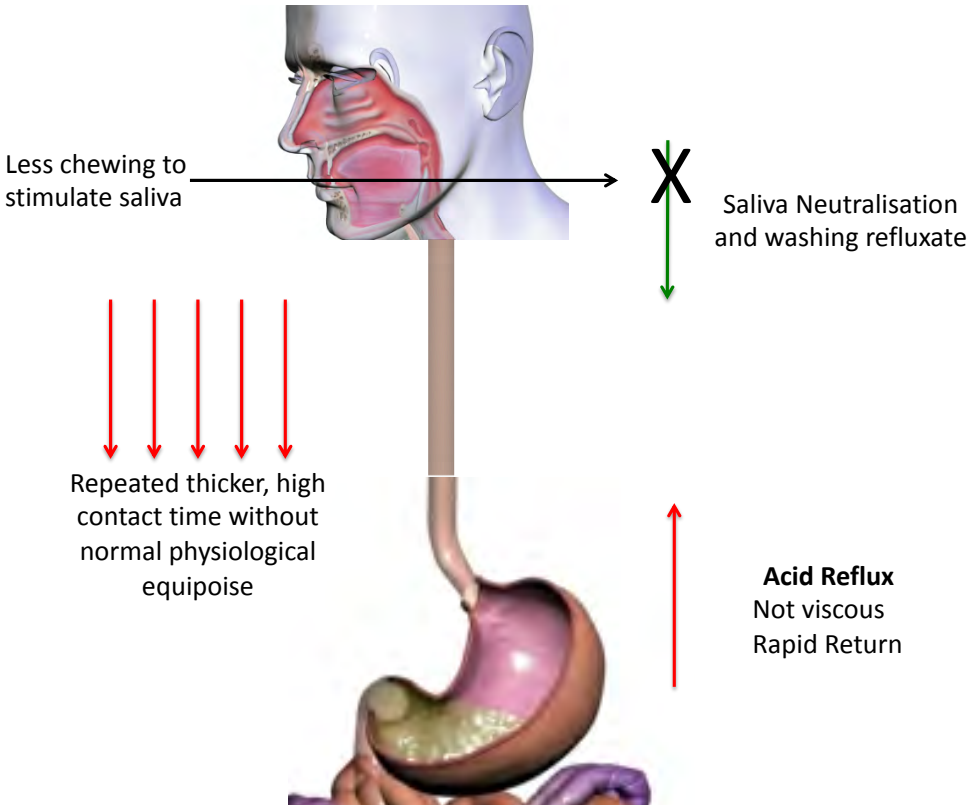

Figure 1: Suggested pathway of epithelial damage