

The effect of cooking method upon the titratable acidity of a popular vegetarian dish – Scope for reducing its erosive potential?

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Abstract - *The purpose of this in vitro study was to determine the effect of cooking method on the erosive potential of ratatouille. Two cooking methods, stewing and oven roasting, were applied to standardised ingredients taken from the same fruits and vegetables. The resultant dishes were liquidised and diluted with 100 mls of distilled water. Five 25 ml samples of each group were titrated to pH 7.0 against 0.1 Molar Sodium Hydroxide. In order to ascertain the relative contribution of each ingredient each was singly prepared and cooked by stewing or oven roasting following the same quantities and dilutions as for the dish as a whole. 25 ml samples of these were titrated to pH 7.0 against 0.1 Molar Sodium Hydroxide. For ratatouille as a dish significantly ($P < 0.0001$) more alkali had to be added to the oven roast group (Mean = 8.60 mls, S.D. = 0.31) than to the stewed group (Mean = 3.92 mls, S.D. = 0.50) in order to bring about neutrality. Oven roasting of ingredients significantly ($P < 0.001$) lowered the initial pH with the exceptions of tomatoes and red peppers. Stewing reduced the volume of alkali required to neutralise aubergine ($P < 0.001$), green peppers ($P < 0.001$) and courgettes ($P < 0.05$). Significantly ($P < 0.001$) more alkali however was required to neutralise stewed red pepper. It was concluded that the method of cooking identical ingredients affects the erosive potential of ratatouille. Although oven roasting results in a higher erosive potential of ratatouille compared to stewing the method of cooking, at an individual ingredient level, does not have a universal effect upon erosive potential as determined by titratable acidity. This should be borne in mind when advising patients.*

KEY WORDS: Erosive potential, acidity, diet preparation

INTRODUCTION

Both the 1993 National Survey of Child Dental Health in the United Kingdom (1) and the more recent National Diet and Nutrition Survey (2) revealed a high prevalence of tooth surface loss due to erosion of the order of 52 - 65 % in children and adolescents. Dental erosion is a multifactorial process that arises from direct acid contact with the teeth. This acid may derive from dietary intake, medication, regurgitation of stomach contents or prolonged exposure to an acidic external environment (3). The precise relationship between acidic risk factors and the erosive process is, however, unclear. Risk factor effects may be modified by both biological contributors (e.g. saliva - composition and flow rate, tooth composition and structure) and behavioural factors (e.g. unusual oral hygiene practices, diet, eating, drinking and swallowing habits) (4). Within the literature some have reported that those on a vegetarian diet may be more at risk from dental erosion (4,5) whereas others (6) have demonstrated no statistically significant difference in the prevalence of erosion in vegetarian as compared to non-vegetarian children. Such a diet offers both advantages and disadvantages and by its very nature contains several acidic foods such as fruits (eg. Oranges and tomatoes) and vegetables (eg. Aubergines and courgettes) which if consumed in excess may be associated with dental erosion. Data are strong that vegetarians are less likely to develop

obesity and lung cancer and good for reduced chance of hypertension, coronary artery disease, diabetes and gallstones (7). In addition, there is a decreased risk of cancer of the colon, breast, lung, oral cavity, larynx, oesophagus, stomach, bladder, uterine cervix and pancreas (8). It is therefore not surprising that recent Food Standard Agency initiatives such as Eat Five (9) promote the daily consumption of fruit and vegetables for well being. A vegetarian dish that in recent years has become popular with both vegetarians and non vegetarians alike is Ratatouille. This may be prepared by either the traditional stewing method or by oven roasting the ingredients. A generally accepted laboratory method of determining the potential of a food or beverage to promote dental erosion is to determine its erosive potential (10) by measuring, by titration, the volume of 0.1 Molar Sodium Hydroxide required to neutralise a standardised volume of beverage/food. Such a technique has previously been used in a number of studies (11-14) and is thought to be a more accurate predictor than the baseline pH as this gives only a measure of the initial hydrogen ion concentration and does not provide any indication as to the presence and effects of undissociated acid. It was the purpose of this work to assess the effect of preparation technique upon the erosive potential of this dish for the purposes of advising patients with erosion.

MATERIAL AND METHODS

The effect of cooking method upon the erosive potential of ratatouille and its individual constituents was determined

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following the methods described below.

Preparation of ratatouille - In order to determine the effect of cooking method upon the erosive potential of ratatouille a standardised recipe was adopted (Table 1). This was applied to two different methods of cooking; stewing and oven roasting. Potential variations in the chemical ingredient composition were minimised by dividing longitudinally each fruit/vegetable into half, using a kitchen knife, and assigning it to either the oven roast or stewed group. Each constituent was cut into 1.5 cm squares and portioned out as detailed in Table 1 by weighing on digital kitchen scales. The ingredients for the stewed group were transferred to a cooking saucepan and those in the oven roast group to a baking tray. To each group 15 mls of extra virgin olive oil were added and the mixture stirred for one minute. The oven roast group was then placed in an oven at 200 °C and roasted for 45 minutes. The stewed group was stir fried for 1 minute after which 100 mls of cold water was added. This was then brought to the boil whilst being constantly stirred. It was then simmered, uncovered and unstirred in the pan for 44 minutes. Thereafter, each cooked group was transferred into a food processor and liquified for one minute prior to storage in a sealed plastic container for 12 hours at 4 °C in a domestic refrigerator.

Preparation of the individual constituents of ratatouille – In order to ascertain the relative contributions to the overall acidity and titratable acidity of the dish each ingredient was separately prepared by stewing and oven roasting from a new fruit/vegetable to that used in preparing the dish. Each ingredient was prepared in the quantity and manner detailed in the standardised recipe (Table 1). Subsequent cooking of each ingredient followed the identical methods to those described for the standardised recipe using the same temperatures, times and volumes of extra virgin olive oil and water. In this way cooked portions of each ingredient resulted in both the oven roast and stewed states. Each was transferred into a food processor and liquified for one minute prior to storage in sealed plastic containers for 12 hours at 4 °C in a domestic refrigerator.

Determination of titratable acidity of the dish as a whole and its individual constituents - Prior to titration each sealed container was removed from the refrigerator and 100 mls of distilled water was added to the cooked ingredients and thoroughly stirred in. For each group five 25 ml samples were measured out and titrated to a pH of 7.0 against 0.1 Molar Sodium Hydroxide whilst being constantly stirred with a magnetic stirrer. Both the initial pH and changes in pH in response to titration were measured using a calibrated temperature compensated pH electrode. The initial pH and volume of Sodium Hydroxide required to reach neutrality were recorded and the mean for each group calculated.

RESULTS

Table 2 summarises the mean initial pH and mean volume of 0.1 Molar Sodium Hydroxide required to neutralise a 25 ml sample of ratatouille prepared by either oven roasting or stewing. The standard deviations of these quantities are also contained within this table. Intergroup comparisons of these quantities, using an unpaired t test and the statis-

tical package Prism, revealed that the mean initial pH of the oven roast group was statistically significantly lower than for the stewed group ($P = 0.0046$). Significantly ($P < 0.0001$) more 0.1 Molar Sodium Hydroxide had to be added to the oven roast group (Mean = 8.60 mls, S.D. = 0.31) than to the stewed group (Mean = 3.92 mls, S.D. = 0.50) in order to neutralise it.

Tables 3 & 4 summarise the mean initial pH values and mean volumes of 0.1 molar Sodium Hydroxide required to neutralise a 25 ml sample of each ingredient prepared by either oven roasting or stewing. The standard deviations of these observations are also contained in these tables. One way analyses of variance revealed highly statistically significant ($P < 0.0001$) differences in both the mean initial pH and volumes of 0.1 molar Sodium Hydroxide (titratable acidity). These were localised by a Tukey comparison of means whose outcomes are also summarised in these tables:

With respect to the mean initial pH (Table 3) - oven roasting resulted in significantly ($P < 0.01$) lower pH values than stewing, with the exceptions of tomatoes and red peppers.

With respect to the mean volume of 0.1 molar Sodium Hydroxide required to bring about neutrality (titratable acidity) (Table 4) – the cooking method did not significantly ($P > 0.05$) effect tomatoes or onions. On the other hand, significantly lower volumes of 0.1 molar Sodium Hydroxide were required to neutralise stewed aubergines ($P < 0.001$), green peppers ($P < 0.001$) and courgettes ($P < 0.05$) than when oven roasted. Oven roasting red pepper however, significantly ($P < 0.001$) lowered the volume of alkali required to bring about neutrality compared to stewing.

DISCUSSION

Although this study sought to determine and compare the erosive potential of ratatouille and its constituents, prepared by two different cooking methods, the absolute degree to which any one would damage the teeth by erosion is not possible to determine since this will vary greatly amongst individuals. This reflects the complex interplay of both behavioural and biological factors that modify the effects of exposure to erosive risk factors (4). Such an observation may account for the differing conclusions of studies (4-6) that have examined the level of erosive risk that a vegetarian diet confers.

The results of the present study demonstrate that, irrespective of the method of preparation, ratatouille is acidic. It is of greater interest to note that oven roasting significantly increases the erosive potential of this dish as demonstrated by the larger mean volume of sodium hydroxide required to raise the samples to neutrality. It could be argued that this is simply a consequence of the relative dilutions of the preparation techniques with a total of 200 mls of water being added to the stewed group compared to only 100 mls to the oven roast. On the other hand such a simplistic approach does not take into account the effects upon the titratable acidity of the complexities of the dilution process, which are not proportionate, upon a dish that is a mixed acid system. It therefore seems more likely that the differ-

Table 1. *The standardised ratatouille recipe.*

<i>Ingredient</i>	<i>Weight (g)</i>
Onion	50
Green pepper	41
Aubergine	60
Courgettes	27
Tomatoes	58
Red pepper	32

Table 2. *The mean initial pH, mean volume of 0.1 molar Sodium Hydroxide and Standard Deviations of these observations required to neutralise 25 mls of ratatouille prepared by oven roasting or stewing.*

<i>Parameter</i>	<i>Oven Roast</i>	<i>Stewed</i>
Initial pH	4.57 (0.23)	5.08 (0.18)
Volume of Sodium Hydroxide required to neutralise a 25 ml sample	8.60 (0.31)	3.92 (0.50)

Numbers in parentheses are the standard deviation of the observations. The number of samples per group was 5.

Table 3. The mean initial pH and Standard Deviations of these observations for 25 ml samples of each ingredient as prepared by oven roasting or stewing.

<i>Method of Cooking/ Fruit/Vegetable</i>	<i>Oven Roast</i>	<i>Stewed</i>	<i>Statistical significance</i>
Tomatoes	4.74 (0.10)	4.17 (0.05)	P < 0.001
Aubergine	3.89 (0.04)	4.36 (0.08)	P < 0.001
Courgette	4.70 (0.05)	6.19 (0.08)	P < 0.001
Green pepper	4.39 (0.02)	5.06 (0.06)	P < 0.001
Red pepper	5.47 (0.18)	4.77 (0.06)	P < 0.001
Onion	3.93 (0.17)	4.95 (0.17)	P < 0.001

Numbers in parentheses are the standard deviation of the observations. The number of samples per group was 5 except for oven roast (all ingredients) and stewed onion where 4 samples were tested.

Table 4. The mean volume of 0.1 molar Sodium Hydroxide required to bring about neutrality of a 25 ml sample of each ingredient (prepared by oven roasting/stewing) together with the Standard Deviations of these observations.

<i>Method of Cooking/ Fruit/Vegetable</i>	<i>Oven Roast</i>	<i>Stewed</i>	<i>Statistical significance</i>
Tomatoes	2.28 (0.34)	2.30 (0.07)	P > 0.05
Aubergine	2.52 (0.22)	0.86 (0.09)	P < 0.001
Courgette	0.92 (0.40)	0.16 (0.06)	P < 0.05
Green pepper	1.70 (0.89)	0.48 (0.08)	P < 0.001
Red pepper	0.67 (0.34)	1.44 (0.08)	P < 0.05
Onion	1.13 (0.33)	1.22 (0.16)	P < 0.05

Numbers in parentheses are the standard deviation of the observations. The number of samples per group was 5 except for oven roast (all ingredients) and stewed onion where 4 samples were tested.

ences in titratable acidity observed reflect differences in the chemistry of the dishes as produced, from identical ingredients, by the different cooking methods. This argument is strengthened further by the changes in titratable acidity observed for the individual ingredients (Table 4) where the method of cooking does not have a universal effect upon this quantity. Clearly such uneven dilutions in the two preparation groups is scientifically untidy, but is absolutely necessary from a practical cooking perspective. Although the subsequent liquidising of ingredients is far more efficient than the comminution of food as a result of mastication, this is required to produce workable solutions for the purpose of titration and was carried out for all samples tested. When the observed titratable acidity of ratatouille is compared to that reported for beverages of considerable erosive potential, such as the alcoholic lemonade Hooch™ (12), cider (14) and orange juice (14) a lesser erosive potential is demonstrated. It should however be recognised that the titratable acidity of ratatouille prepared by oven roasting is the same as for some carbonated drinks that, when consumed in excess, are believed to contribute to the development of dental erosion (15). This is something to bear in mind when advising patients who may be inclined to consume this dish in excess as to the risk of developing dental erosion. Clearly, on the data presented in this paper, it would be possible to recommend a less erosive form of the dish by suggesting the omission of the more erosive ingredients. Such advice would have to take into account the preferred cooking method. It may prove unacceptable to the consumer for the balance of texture and flavour could be upset adversely.

CONCLUSION

The method of cooking identical ingredients affects the erosive potential of ratatouille. Although oven roasting results in a higher erosive potential of ratatouille compared to stewing the method of cooking, at an individual ingredient level, does not have a universal effect upon erosive potential as determined by titratable acidity. This should be borne in mind when advising patients.

MANUFACTURERS' DETAILS

- Digital Kitchen Scales – Soehnle, Switzerland.
- Extra Virgin Olive Oil – Phillipio Berio, Salov s.p.a., Italy
- Food Processor – Braun Multipractic, Kronberg, Germany.
- Refrigerator – Zanussi Refrigerator/Freezer ZA 98/3 W.,

Slough, Berkshire, UK.

- pH Electrode – Piccolo ATC, Hanna Instruments Inc., Highland Business Park, 584 Park East Drive, Woonsocket, 02895, USA.
- Prism Statistical Package – Version 4.0, GraphPad Software Inc., 5775 Oberlin Drive #110, San Diego, CA 92121, USA.

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REFERENCES

1. O'Brian M. Childrens Dental Health in the United Kingdom 1993. 1994; Office of population Censuses and Survey's. Her Majesty's Stationary Office, London.
2. National Diet and Nutrition Survey (2000) Young people aged 4 to 18 years; Vol 2; report of the oral health survey. TSO, London 2000.
3. Ten Cate J.M. and Imfeld T. Dental erosion, Summary. *European Journal of Oral Sciences* 1996; **104**: 241-244.
4. Zero D.T. Etiology of dental erosion - extrinsic factors. *European Journal of Oral Sciences* 1996; **104**: 162-177.
5. Linkosalo E. and Markkanen H. Dental erosion in relation to lactovegetarian diet. 1985; *Scandinavian Journal of Dental Research* **93**: 436-441.
6. Al-Dlaigan Y.H., Shaw L. and Smith A.J. Vegetarian children and dental erosion. *International Journal of Paediatric Dentistry* 2001; **11**: 184-192.
7. Dwyer J.T. Health aspects of vegetarian diets. *American Journal of Clinical Nutrition* 1988; **48** (Supplement 3): 712-738.
8. Steinmetz K.A. and Potter J. D. Vegetables, fruit and cancer. I. epidemiology. 1991; *Cancer Causes Control* **2**: 325-357.
9. Food Standards Agency – Your Daily Diet. <http://www.food.gov.uk/healthiereating/dailydiet/>
10. Edwards M., Creanor S.L., Foye R.H. and Gilmour W.H. Buffering capacities of soft drinks: the potential influence on dental erosion. *Journal of Oral Rehabilitation* 1999; **26**:923-927.
11. Lussi A., Jaeggi T. and Jaeggli-Scharer S. Prediction of the erosive potential of some beverages. 1995; *Caries Research* **29**: 349-354.
12. Rees J.S., Burford K. and Loyn T. The erosive potential of the alcoholic lemonade Hooch. 1998; *European Journal of Prosthodontics and Restorative Dentistry* **6**: 161-164.
13. Cairns A.M., Watson M., Creanor S.L. and Foye R.H. The pH and titratable acidity of a range of diluting drinks and their potential effect on dental erosion. 2002 *Journal of Dentistry* **30**: 313-317.
14. Rees J.S. and Griffiths J An in vitro assessment of the erosive potential of conventional and white ciders. *European Journal of Prosthodontics and Restorative Dentistry* 2002; **10**:167-171.
15. Chadwick R. G. (2000) Practitioner evaluation of an erosive potential data sheet. *Journal of Dental Research* **79**: 1197, Abs no. 210.