B.I.T.E (BISCUIT INCIDENT THREAT EVALUATION)

ABSTRACT

Independent research, commissioned by Rocky, has determined the following formula for use as guidance when trying to estimate the risk associated to eating particular types of biscuits:

$$B.I.T.E = 6\mathrm{P}_{\mathrm{DK}}\,\mathrm{W}_{\mathrm{ST}}\;(1 - \delta\,\mathrm{S}_{\mathrm{CAP}}) + 9.9\varepsilon\,\mathrm{S}_{\mathrm{TB}} + 40\mathrm{F}_{\mathrm{MX}}[1 - \vartheta^{0.1\mathrm{N}_{\mathrm{CH}}}] + 1000\mu\mathrm{L} + 400[\alpha\,\mathrm{E}_{\mathrm{NR}} + \beta\,\mathrm{E}_{\mathrm{LR}} + \rho\,\mathrm{N}_{\mathrm{CH}}]$$

The expression depends on two types of factors;

1) Biscuit dependent properties as summarised in Appendix 5.
2) Consumer dependent properties as summarised in Appendix 2.

DISCLAIMER: THIS FORMULA HAS BEEN CALCULATED BASED UPON ONLY THE MOST OBVIOUS TYPES OF INJURIES AND BASED UPON COMMON BISCUIT-EATING BEHAVIOR TYPES. IT IS STRONGLY RECOMMENDED THAT THE INDIVIDUAL CONSULT THE BISCUIT MANUFACTURER AND PERFORM A SELF ASSESMENT OF THEIR PARTICULAR RISK PRIOR TO EATING BISCUITS

STUDY OBJECTIVE

The aim of the study was to identify the potential risks associated with biscuits and to quantify these risks to create a mathematical model (B.I.T.E)

INTRODUCTION

According to statistics from 'The Home Accident Surveillance System' 2002 report by the Department of Trade and Industry, there were more than 500 'biscuit related' accidents in that year, or around ten each week. To investigate just what it is about this humble and apparently innocent looking snack food, we asked students to investigate their physical characteristics.

METHODOLOGY

The study, supervised by Mindlab International Ltd scientists, involved ten students (5xM & 5xF) aged 16 -18 (average 17.2) to investigate the physical properties of biscuits. Experimental work was carried out at the Sussex Innovation Centre based at the University of Sussex in Brighton.

Once this had been completed the B.I.T.E. factor was mathematically computed using both the research data and responses from a national survey involving over one thousand respondents across the UK.

Each risk relates to the physical properties of a biscuit. These physical properties were tested in the laboratory and the procedures for investigation noted. 15 varieties of biscuits were tested.

ANALYSIS & RESULTS

The standard method for quantifying the risk of a particular event relies upon two factors.

1. The probability of the event occurring P(E).
2. The cost (not necessarily in financial terms) of the event C(E).

In the case where many different events can contribute to the risk, the total risk (R_{total}) is given by adding up all the individual risks involved.

$$R_{total} = \sum P(E)C(E)$$

Thus the task can be broadly separated into three distinct tasks;

A. Identifying all the events that pose a risk in the given scenario.
B. Calculating the probabilities of these events occurring.
C. Estimating the cost associated to each event.

IDENTIFYING THE RISKS

The following risks were determined as most likely to occur:

1. Eye/ear/trachea (windpipe) irritation caused by crumbs.
2. Scalding – due to splashes caused when a piece of dunked biscuit falls into hot liquid.
3. Back Injury, hernia, muscular problems from picking up dropped biscuit pieces.
4. TMJ (temporomandiular joint) syndrome to jaw by frequent biscuit chewing.
5. Workplace injury due to being distracted by the sound of biscuits being broken.
6. Dental Damage due to biting on a hard biscuit or something within the biscuit, such as a nut or piece of hard chocolate. Especially likely to cause damage if the tooth has previously been filled.

FACTOR 1. IRRITATION DUE TO CRUMBS ENTERING THE EYES OR EARS.

Crumbs were identified as being a risk due to the possibility of them irritating the surface of the eye, entering the ear or becoming lodged in the windpipe when swallowing.

The probability of such a risk is the combined probability of two separate events occurring.

1. A crumb enters the eye, ear or windpipe – probability P(*into eye/ear*).
2. The crumb causes significant irritation – probability P(*irritation*).

The probability of both these occurring:

P(irritation) = P(*into eye/ear/windpipe*) x P(*irritation*).

The first probability (crumb propensity) is a measurable property of the particular biscuit while the second must be estimated. For obvious safety reasons, laboratory work did not involve trials in which vulnerable body parts were repeatedly impacted by biscuit crumbs!

A standard material data sheet for biscuit crumbs states the hazard identification as:

1. *Contains substances, which may cause sensitisation, allergic or irritant response.*

2. *Inhalation of dust may induce sensitisation and may cause allergic reactions in sensitised individuals. It may also cause irritation of the respiratory tract e.g. rhinitis. Prolonged skin contact may cause contact dermatitis and /or/ minor irritation. The product is combustible and when handling fine powdered products there is a risk of dust explosions.*

3. *Contact with eyes will cause irritation.*

Reference: British Bakels, MSDS for digestive biscuit crumbs.

The team of experts has estimated that there is a 1 in 50 chance that a crumb entering either the ear/eye or windpipe with force will cause significant irritation;

$$P(\text{crumb } \textit{irritation}) = 1/50 = 0.02$$

The next stage was to identify the probability that a crumb will get into the eye, ear or trachea (windpipe).

This is related to a property of the particular biscuit in question – namely its propensity (EXPL) to project crumbs away from itself when broken or bitten.

In order to calculate the EXPL, one hundred biscuits, of different types, were broken under controlled conditions and the average number of crumbs traveling further than the typical biscuit to eye/ear distance (estimated to be 50cm when broken (E_{BR}) and 10cm when bitten (E_{BT10}). For the windpipe this distance was reduced to 5cm (E_{BT5}) bitten.

$$E_{BR} = \text{average number of crumbs travelling} > 50\text{cm when broken}$$

$$E_{BT10} = \text{average number of crumbs travelling} > 10\text{cm when bitten (eye/ear).}$$

$$E_{BT5} = \text{average number of crumbs travelling} > 5\text{cm when bitten (trachea)}$$

Since, typically, crumbs will be spread out in all directions it was necessary to estimate the relative target areas.

For the eyes and ears this area was estimate to be $1cm^2$. Since the vast majority of people have two of each the probability of a single crumb entering the eye/ear (at a distance of 50cm) is given as $4cm^2$ (eye + ear area) divided by the area of a sphere with radius 50cm;

$$P(\textit{broken crumb getting in the eye/ear}) = 4cm^2 / 4\pi(50cm)^2,$$

$$P(\textit{bitten crumb getting in the eye/ear}) = 4cm^2 / 4\pi(10cm)^2.$$

Similarly it is estimated that the average windpipe is 1 cm^2 in area and begins approximately 5cm from the teeth. In addition it is also assumed that people who break biscuits generally have their mouths closed. Thus the following probability is associated to getting crumbs in the windpipe;

$$P(\textit{bitten crumb getting in the trachea}) = 1cm^2 / 4\pi(5cm)^2$$

Assembling all the above information the following expression is associated to the probability of getting a crumb into either the ear, eye or windpipe,

$$P(\textit{into eye/ear due to breaking}) = \frac{1}{4\pi}\frac{E_{BR}}{50^2}$$

$$P(\textit{into eye/ear/trachea due to biting}) = \frac{1}{4\pi}\left[\frac{E_{BT10}}{10^2} + \frac{E_{BT5}}{5^2}\right].$$

In order to estimate the risks associated the general populous the following survey information was obtained;

82.22% of those surveyed prefer to bite into their biscuits.

10.11% of those surveyed prefer to break pieces off the biscuit.

Hence the following probability of getting a crumb projected into a potentially hazardous body part can be associated to a biscuit;

$$P(\text{contact}) = \frac{1}{4\pi}\left[0.8222 \times \left(\frac{E_{BT10}}{10^2} + \frac{E_{BT5}}{5^2}\right) + 0.1011 \times \frac{E_{BR}}{50^2}\right]$$

Combining these factors we find that probability value associated with this risk factor is:

$$P(\text{irritation}) = P(\textit{contact}) \times P(\text{crumb } \textit{irrit})$$

It only remains to calculate the likely cost of this particular injury $C(\textit{irritation})$.

The method adopted for assigning a cost to this particular event was to determine the typical payout that required a visit to the opticians/medical specialists for treatment. This was estimated at £400, taking into account the cost of any arranging and traveling to the treatment centre and loss of productive time at work. This is assuming that the individual sought treatment under the NHS. Clearly if the specialists were seen privately this cost would be significantly higher.

$$C(\textit{irritation}) = £400.$$

Thus we have completed the risk assessment associated to biscuit blindness.

$$R(\textit{irritation}) = P(\textit{irritation}) \times C(\textit{irritation})$$

$$= \frac{400}{4\pi} \mathrm{P(crumb\ irrit)} \left[\mathrm{P}(bite) \times \left(\frac{\mathrm{E_{DT10}}}{10^2} + \frac{\mathrm{E_{DT5}}}{5^2} \right) + \mathrm{P}(break) \times \frac{\mathrm{E_{DR}}}{50^2} \right]$$

In order to simplify the expression for the probability of irritation being caused we use the following simplifications,

Near range explosiveness $E_{NR} = E_{BT10}/10^2 + E_{BT5}/5^2$

Long range explosiveness $E_{LR} = E_{BR}/50^2$

And by defining α and β as;

$$\alpha = 400 \times \mathrm{P}(bite) \times \mathrm{P(crumb\ irrit)} / 4\pi$$
$$\beta = 400 \times \mathrm{P}(break) \times \mathrm{P(crumb\ irrit)} / 4\pi$$

The equation can be simply written as:

$$\mathrm{P(irritation)} = \alpha\, E_{NR} + \beta\, E_{LR}$$

FACTOR 2. RISK OF SCALDING WHEN RETRIEVING BISCUIT PARTS FROM A HOT BEVERAGE.

The probability of such an event is the product of the following factors:

$$P(\textit{dunking}) \times P(\textit{probability of burns due to dunking})$$

While the probability of the biscuit in question being dunked and the probability of attempting to retrieve any lost biscuit are subjective, an estimate was determined from the survey responses.

In the survey most respondents (51.8%) admitted that they would attempt to retrieve any lost biscuit segment thus giving the probability of retrieval as:

$$P(\textit{retrieval}) = 0.518$$

The survey showed that the typical biscuit is dunked approximately twice. This was repeated in laboratory studies and the probability of a significant piece falling off calculated – P(structural biscuit failure).

The 'splash' caused by such a fall was measured and it was found that if more than 2ml of sufficiently hot liquid was displaced a significant scolding could occur.

The amount of fluid displaced (in ml) is termed the DISP. Combining these two factors we obtain the risk of getting minor scolding.

$$P(\textit{scold}) = P(\textit{structural biscuit failure})[\,1-(1-\theta(\mathrm{DISP}-2))(1-P(\textit{retrieval}))]$$

Where θ (DISP-2) = 1 if DISP>2 and zero otherwise.

The likely cost of such an injury is estimated to be the price of scald relief spray which is approximately £6 (*www.boots.com 19/08/09*). It is not possible to assign a value to any loss of productivity caused by a painful finger scald but clearly this could prove an additional cost in some instances. Thus the total risk of this type of biscuit related injury is:

$$\mathrm{Risk}(\textit{minor scold}) = 6 \times P(\textit{scold}) \times P(\textit{dunking})$$

- given that some biscuits are more likely to be dunked than others.

As before simplifications are introduced,

Wet strength	W_{ST} = P(structural biscuit failure)
Splash capacity	S_{CAP} = 1-θ(DISP-2)
Dunk probability	P_{DK} = P(dunking)

And also defining δ;

$$\delta = 1 - P(\textit{retrieval})$$

Thus enabling us to write the equation for factor 3 as:

$$P(\text{scolding}) = P_{DK}\, W_{ST}\, (1 - \delta\, S_{CAP})$$

FACTOR 3. RISK ASSOCIATED TO POTENTIAL BACK STRAIN

Back strain was identified as a potential risk should a piece of biscuit fall to the ground and cause an injury when retrieved.

The survey showed that almost everyone (98%) would stoop to pick up a piece of biscuit, a third (31%) to eat it and almost seven out of ten (67%) to bin it. The probability of this occurring:

$$P(retrieval)=P(bin)+P(pick\ up\ an\ eat)$$

Therefore P(retrieval) equals 0.98.

In the laboratory, 100 biscuits were broken under controlled conditions and the probability of a significant piece falling to the floor calculated – P(fall).

The costs associated with such an injury was conservatively based on the price of a heat pack to ease the muscle strain together with the price of a small bottle of OTC (Over the Counter) anti-inflammatory pills - £9.90 *(www.boots.com 19/08/09)*. As with the previous factor, if medical attention were sought then the costs, at least in time spent, would significantly increase the costs of such an injury.

In addition it is required that the probability of injury resulting from bending down to pick up any particular piece of biscuit be estimated. Of course this is dependent on the health and physical ability of the biscuit eater in question. However after deliberation between our experts who made the observation that the elderly (and more at risk) are more likely to enjoy a biscuit whist sitting down (thus requiring additional movement) the following figure was arrived at;

$$P(\text{injury from bending down once})=1/1{,}000.$$

Thus the risk here is given as:

$$R(\text{muscle strain})=9.9 \times P(\text{fall}) \times [\ P(bin)+P(pick\ up\ and\ eat)\ ] \times P(injury)$$

$$R(muscle\ strain) = 9.702 \times P(fall) \times P(injury).$$

Again this is simplified using the following substitutions:

Fall probability: $S_{TB} = P(fall)$

And also defining ε as;

$$\varepsilon = P(injury)$$

The equation for factor 3 can be simply written as:

$$P(strain) = \varepsilon \, S_{TB}$$

FACTOR 4. TMJ SYNDROME

The temporomandiular joint (TMJ) connects the lower jaw called the mandible to the temporal bone at the side of the head, situated just in front of your ears. The TMJ joint is one of the most frequently used joints in the body, moving up to 2,000 times every day, or 730,000 times per year. It is used when you talk, chew and also in the action of swallowing. Muscles that attach and surround the jaw joint control its position and movement.

Jaw pain (TMJ syndrome) is a very common problem that affects people of all ages, although those under 40 are more susceptible and it occurs more frequently in women.

The survey showed that, on average, each person in the UK consumes some 18 biscuits a week or 936 per year. This results in approximately AVG = 2.56 biscuits per day.

Using the assumption that all biscuit eating contributes on top of the 2000 chews/day, our experts estimated that a 1000% increase in mandiular activity posed a 30% increase in the risk of TMJ syndrome.

The relationship between the risk of TMJ disorder and the number of repetitions (N_{CH}) is given by:

$$P(TMJ)= (0.3 \times N_{CH} \times AVG /102000).$$

Since, as the survey showed, the average person consumes 936 biscuits a year, the next factor to determine is the average number of chews required for the biscuit in question. This is termed the CHEW factor.

Laboratory research was conducted on the most common biscuit types and their tabulated results are presented in appendix 3.

The likely cost of TMJ syndrome was calculated by combining the time involved in visiting a GP together with prescription charges (for those who pay them) incurred for any medication prescribed. This has been conservatively estimates at £400 per year. As mentioned above, where private medical advice is sought these costs would be considerably elevated.

$$R(TMJ) = £400 \times P(TMJ) \times CHEW$$

Again the probability is simplified using the following definition

$$\rho = 0.3 \times AVG / 102000$$

Thus the equation for factor 4 can be written as:

$$P(TMJ) = \rho\, N_{CH}$$

FACTOR 5. DENTAL PROBLEMS ASSOCIATED WITH DENSELY ARRANGED CLUMPS (VISCOSITY).

The harder a biscuit, the greater the probability of tooth damage being caused either in terms of its overall consistency or of items, (i.e. nuts, pieces of chocolate within it.) The risk is increased for teeth that have been filled.

The national survey showed that the average number of teeth with fillings in the UK is four.

The laboratory research indicated that biting down on a lump capable of sustaining a force of 50 Newtons presents a probability of 10% (1 in 10) of causing damage to a filling. It was estimated that no filling could survive an attack by over 500 Newtons of force. Extrapolating this gives an estimate of the probability of a lump causing damage to be:

$$P(\textit{lump causing damage}) = F_{MAX} / 500.$$

Given that there are 32 teeth in the human mouth, the probability of ***not*** biting down on a hard lump with a tooth containing a filling is:

$$P(\textit{not biting with filling}) = (32 - N_{filling}) / 32$$

It was estimated that only the first 10% of chews pose a significant threat, since saliva will rapidly soften even the hardest biscuit.

$$N_{DANGEROUS\ BITES} = 0.1 \times N_{CH}$$

By combining these equations, the probability of biting down on at least one filling during the initial (most dangerous) period of consuming a biscuit is:

$$P(\textit{filling damage}) = [1 - P(\textit{not biting with filling})^{0.1xNCH}] \times P(\textit{lump causing damage})$$

The cost of a replacement filling is known to be around £40 (NHS) thus the cost associated to this is calculated to be.

$$C(\textit{filling damage}) = P(\textit{filling damage}) \times 40$$

The probability is simplified using the following definition:

Maximum force $F_{MX} = F_{MAX}/500$

φ can be defined as;

$$\vartheta = (32 - N_{filling}) / 32$$

The equation for factor 5 can therefore be written as:

$$F_{MX}[1 - \vartheta^{0.1N_{CH}}]$$

FACTOR 6. DISTRACTION CAUSING WORK RELATED INJURIES

This factor is caused by excessive biscuit noise causing accidents in the workplace as a result of distraction.

Laboratory investigation showed that, when broken, biscuits create a noise of between 5dB and 15dB when broken.

It was further observed that noises of 10dB were perceived as distracting in by six out of ten (60%) people where as at 5dB the noise was only regarded as distracting by one person in five (20%).

The average loudness L_{OUD} was measured for the most common biscuits. Thus using linear extrapolation the probability of audible perception, P(hear it),in a quiet environment, is estimated as:

$$P(\textit{hear it}) = (0.4/5 \times L_{OUD} - 0.2)$$

The above formula being valid in the operational range of 5-15dB which covers all biscuits tested.

An estimation that this will cause injury clearly depends on the nature of the work being undertaken. What might in an office be merely an irritating distraction could, if for example work requiring a high degree of precision or hand eye co-ordination was involved, cause a serious and possibly costly mistake to occur.

It is estimated that 1 in 3,000 sudden distractions in the workplace may potentially lead to an injury thus the probability associated to a work related injury cause by biscuit distraction can be estimated as follows.

$$P(\textit{injury because of biscuit noise}) = P(\textit{hear it}) \times P(\textit{injury due to hearing it})$$

$$= (0.08 \times L_{OUD} - 0.2)/3{,}000.$$

Some work injuries are extremely dangerous and the cost for these is difficult to estimate. However our panel agreed that a fair working assumption for the case of biscuit related injuries would amount to an injury costing approximately £1,000 for rehabilitation.

C(*injury because of biscuit noise*)=(0.08 x L_{OUD} – 0.2) x 40/3

Simplifying,

L=0.08 x L_{OUD}-0.2

μ = P(*injury due to distraction*)

The probability of a distraction related incident can be written as:

$$\mathrm{P(Distraction\ Related)} = \mu \mathrm{L}$$

APPENDIX 1 - BUILDING THE FORMULA

As a result of careful experimentation, deliberation and research, the following risk probabilities have been identified. This table summarises the results of the main text.

INJURY TYPE	PROBABILITY	COST (£)
Irritation	$\alpha E_{NR} + \beta E_{LR}$	400
Scolding	$P_{DK} W_{ST} (1 - \delta S_{CAP})$	6
Strain	εS_{TB}	9.9
TMJ	ρN_{CH}	400
Dental problems	$F_{MX}[1 - \vartheta^{0.1 N_{CH}}]$	40
Distraction related	μL	1000

Putting these factors together the following two expressions for the complete B.I.T.E formula are derived:

$$B.I.T.E = \begin{pmatrix} \alpha\, E_{NR} + \beta\, E_{LR} \\ P_{DK}\, W_{ST}\,(1 - \delta\, S_{CAP}) \\ \varepsilon\, S_{TB} \\ \rho\, N_{CH} \\ F_{MAX}[1 - \vartheta^{0.1N_{CH}}] \\ \mu L \end{pmatrix} \cdot \begin{pmatrix} 400 \\ 6 \\ 9.9 \\ 400 \\ 40 \\ 1000 \end{pmatrix}$$

Or we can present it in the following manner as a standard algebraic equation;

$$B.I.T.E = 6P_{DK}\, W_{ST}\ (1 - \delta\, S_{CAP}) + 9.9\varepsilon\, S_{TB} + 40F_{MX}[1 - \vartheta^{0.1N_{CH}}] + 1000\mu L + 400[\alpha\, E_{NR} + \beta\, E_{LR} + \rho\, N_{CH}]$$

APPENDIX 2 DEFINITIONS OF THE FACTORS

Here the factors that contribute to the formula are summarised along with the general values obtained from the population survey data (appendix 4).

SYMBOL	DEFINITION	GENERAL POPULATION VALUES
α	$\frac{1}{4\pi} \times \mathrm{P(bite)} \times \mathrm{P(irritation)}$	0.0129
β	$\frac{1}{4\pi} \times \mathrm{P(break)} \times \mathrm{P(irritation)}$	0.00158
δ	$1 - \mathrm{P}(retrieve)$	0.482
ε	$\mathrm{P}(pick\ up) \times \mathrm{P}(injury)$	0.00098
ϑ	$\frac{32 - \mathrm{N_{FILL}}}{32}$	0.875
ρ	$\frac{0.3\ \mathrm{Avg}}{10200}$	7.529E-6
μ	$\mathrm{P}(injury\ due\ to\ distraction)$	0.00033

APPENDIX 3 – SOME COMMON BISCUIT PROPERTIES

Below are listed the experimental averages of the biscuit properties indicated in the main text;

BISCUIT NAME	E_{BR}	E_{BT10}	E_{BT5}	P(fail)	DISP	P(fall)	N_{CHEW}	F_{MX}	VOL	P(dunk)
Chocolate Biscuit Bar – Rocky	0.448	0.686	1.572	0.10	6.5	0.03	85	50	12.7	0.87
Bourbon	0.607	1.302	2.804	0.50	1	0.01	36	50	8.1	0.65
Custard Cream	0.1	0.325	0.85	0.83	2.5	0.20	31	46	10.2	0.78
Digestive	0.8	0.412	1.024	0.50	2	0.07	70	40	6.1	0.42
Rich Tea	0.34	0.86	1.92	0.50	1.25	0.73	54	25	14	0.97
Ginger Nut	1.222	1.494	3.188	0.20	1.6	0.05	48	36	13.8	0.71
Oat Biscuit	1.182	1.013	2.226	0.25	1.75	0.80	56	46	9.8	0.63
Cookie	0.268	0.367	0.934	0.17	7	0.13	88	50	13.2	0.81
Chocolate Finger	0.051	0.2382	0.6764	0.10	2.5	0.01	22	28	9.2	0.69
Shortbread	0.3	0.442	1.084	0.11	8	0.53	55	46	14.9	0.36
Wafer	0.508	0.813	1.826	0.09	4.25	0.07	90	50	8.3	0.18
Caramel Shortcake	0.24	0.367	0.934	0.20	1	0.20	56	50	7.7	0.22
Jaffa Cakes	0.058	0.06	0.32	0.50	4.25	0.13	30	25	5.2	0.09
Iced Biscuits - Party Rings	0.72	0.763	1.726	0.25	0.25	0.07	29	50	8.3	0.31
Nice Biscuit	0.465	0.361	0.922	0.50	0.1	0.07	37	15	9.8	0.83

The re-expression of the primary experimental data is shown in the following table, these represent the simplified factors.

BISCUIT NAME	E_{NR}	E_{LR}	W_{ST}	S_{CAP}	S_{TB}	F_{MX}	L	N_{CH}	P_{DK}
Chocolate Biscuit Bar - Rocky	0.0697	0.0002	0.10	0.00	0.03	0.10	0.816	85	0.87
Bourbon	0.1252	0.0002	0.50	1.00	0.01	0.10	0.448	36	0.65
Custard Cream	0.0373	4E-05	0.83	0.00	0.20	0.09	0.616	31	0.78
Digestive	0.0451	0.0003	0.50	1.00	0.07	0.08	0.288	70	0.42
Rich Tea	0.0854	0.0001	0.50	1.00	0.73	0.05	0.92	54	0.97
Ginger Nut	0.1425	0.0005	0.20	1.00	0.05	0.07	0.904	48	0.71
Oat Biscuit	0.0992	0.0005	0.25	1.00	0.80	0.09	0.584	56	0.63
Cookie	0.041	0.0001	0.17	0.00	0.13	0.10	0.856	88	0.81
Chocolate Finger	0.0294	2E-05	0.10	0.00	0.01	0.06	0.536	22	0.69
Shortbread	0.0478	0.0001	0.11	0.00	0.53	0.09	0.992	55	0.36
Wafer	0.0812	0.0002	0.09	0.00	0.07	0.10	0.464	90	0.18
Caramel Shortcake	0.041	1E-04	0.20	1.00	0.20	0.10	0.416	56	0.22
Jaffa Cakes	0.0134	2E-05	0.50	0.00	0.13	0.05	0.216	30	0.09
Iced Biscuits - Party Rings	0.0767	0.0003	0.25	1.00	0.07	0.10	0.464	29	0.31
Nice Biscuit	0.0405	0.0002	0.50	1.00	0.07	0.03	0.584	37	0.83

APPENDIX 4 - AVERAGE NATIONAL BEHAVOUR

The following average values or probabilities are estimated from the survey data collected from over 1000 biscuit eaters.

P(bite)	82.2 %
P(break)	10.1 %
P(retrieval)	51.8 %
P(bin)	67 %
P(pick up and eat)	31 %
A_{DAILY}	2.56
N_{FILL}	= 4

APPENDIX 5 SUMMARY OF BITE FACTORS

The experimental methods and measures are summarised below,

FACTOR	SIMPLIFIED EXPRESSION	DESCRIPTION
Near Range Explosiveness Long Range Explosiveness	$E_{NR} = E_{BT10}/10^2 + E_{BT5}/5^2$ $E_{LR} = E_{BR}/50^2$	Measure probability of crumb dispersion
Wet Strength	$W_{ST} = P(\text{failure})$	Probability of losing a chunk
Splash Capacity	$S_{CAP} = 1\text{-}\theta(DISP\text{-}2)$	Measure of splash likelihood
Dunk Likelihood	$P_{DK} = P(\text{dunking})$	Self Explanatory
Fall Likelihood	$S_{TB} = P(\textit{fall})$	Probability of a piece falling to floor that is worth eating
Max Force	$F_{MX} = F_{MAX}/500$	Average maximum sustainable force of biscuit clumps in Newtons
Loudness	$L=0.08 \times L_{OUD}\text{-}0.2$	L_{OUD} is average breakage volume in dB
Number of Chews	N_{CH}	Average number of chews required

APPENDIX 6 BITE INDEX FOR POPULAR BRANDS

Below is presented the risk index associated to the most popular types of biscuits.

BISCUIT NAME	B.I.T.E
Chocolate Biscuit Bar - Rocky	4.12
Bourbon	3.44
Custard Cream	5.64
Digestive	3.14
Rich Tea	3.45
Ginger Nut	2.99
Oat Biscuit	3.31
Cookie	4.34
Chocolate Finger	1.38
Shortbread	2.90
Wafer	3.74
Caramel Shortcake	2.76
Jaffa Cakes	1.16
Iced Biscuits - Party Rings	2.16
Nice Biscuit	2.27

APPENDIX 7 – CREATING A MACRO AND USING THE FORMULA

In the formula, the Greek letters (α β δ ε φ etc) correspond to numbers that are fixed constants that combine survey data and estimates. For creating the macro we suggest you simply replace them with the values in APPENDIX 2.

The Latin factors are explained below;

NEAR RANGE EXPLOSIVENESS

In order to calculate this factor you need to break a biscuit several times and calculate the average number of crumbs that travel more than 5,10 and 50cm respectively. Then apply the formula below;

$E_{NR} = E_{BT10}/10^2 + E_{BT5}/5^2$

$E_{LR} = E_{BR}/50^2$

where

E_{BT5} = average number of crumbs travelling > 5cm from break point

E_{BT10} = average number of crumbs travelling > 10cm from break point

E_{BR} = average number of crumbs travelling > 50cm from break point

WET STRENGTH

Dunk the biscuit twice for approx 1 second each time. If a significant piece (>5p coin) falls off record this as a failure. Do this several times and record the average number of pieces that fall.

$W_{ST} = P(\text{failure})$

SPLASH CAPACITY

Drop a significant piece (>5p coin) into a glass of liquid from a height of 30cm record the volume of liquid displaced from the glass by the splash of the biscuit. Repeat several times to obtain the average value DISP in ml. Use this to obtain the value for S_{CAP}

$$S_{CAP} = 1-\theta(DISP-2)$$

Remember $\theta(DISP-2)$ is zero if DISP < 2 and equal to 1 if DISP > 2.

DUNK LIKLIHOOD

This is a subjective measure and the individual must assess the probability that the biscuit in question would be dunked. We have some values in the report from a brief survey. The value must be between 0 and 1 e.g. score 0.1 as a 10% likelihood and 0.9 as a 90% likelihood.

FALL LIKLIHOOD

Break biscuit and record on average how often a piece (>5p) falls to the floor. This is used to estimate the fall probability $P(fall)$. The value must be between 0 and 1 e.g. score 0.1 as a 10% likelihood and 0.9 as a 90% likelihood.

$$S_{TB} = P(fall)$$

MAXIMUM FORCE.

Break the biscuit into small pieces and then subject each biscuit clump to a recorded pressure using a Newton meter. The maximum force resisted by the biscuit on average F_{MAX} is then divided by 500 to give the factor to be inserted into the formula.

$$F_{MX} = F_{MAX}/500$$

LOUDNESS

Break biscuit several times in a quiet location and record the average volume of the break in dB (L_{OUD}). Calculate the factor below for insertion into the formula

$$L = 0.08 \times L_{OUD} - 0.2$$

NUMBER OF CHEWS

Eat as many biscuits as you can and each time record the number of chews required before swallowing the biscuit, N_{CH}.