What Kind of Hot Is It?

A survey of the sensory profiles of pungent extracts in liquid and solid food applications

Shane McDonald, Polly Barrett and Lindsay Bond, Kalsec Inc.

What spice or spice extract should be used in seasonings, and is there a difference between the heat in black pepper and that found in ginger?

The sensation of heat provided by certain spice extracts creates another dimension in spicy foods. What would Mexican or Italian dishes be like without the burn of peppers? Chemically, this heat is caused by sensates—compounds that cause sensations in the mouth such as heat, cooling and tingle—found naturally in spices.[1] Examples include capsaicin in chili peppers, piperine in black pepper and gingerol in ginger. Pungency can also be perceived by the nasal tissues in the case of mustards and horseradish. These sensations are not taste *per se*, but rather a chemical sensitivity called chemesthesis, which affects overall flavor impression.[2]

Food processors often prefer to use extracts such as oleoresins (OR) and essential oils instead of spices because the extracts are more concentrated, less variable in sensory properties and less likely to be contaminated with microorganisms. Furthermore, quality OR and essential oil products are tested to ensure they are pesticide compliant and are not adulterated with such things as illegal colorants.

But what spice or spice extract should be used in seasonings? Is there a difference between the heat in black pepper and that found in ginger? Does the impact of pungent principles differ in water-soluble applications, fat-soluble applications and dry applications?

Pungent Spice Extracts

Some of the most common pungent spices are chili peppers, black pepper and ginger. Chili peppers include *Capsicum annuum* (bell pepper, jalapeno, etc), *C. frutescens* (such as tabasco), and *C. chinense* (such as habanero). The pungent compounds in these spices are capsaicinoids, including capsaicin, dihydrocapsaicin and nordihydrocapsacin.[3] These compounds are extremely pungent, measuring about 16 million Scoville heat units (SHU).[1] The OR are an excellent way to obtain natural capsaicinoids, as these compounds are not volatile and not found in the essential oils. The OR are typically standardized for a specific heat rating, measured either in SHU or in percent major capsaicins.

Black and white peppers are derived from *Piper nigrum*. The pungent principles found in black and white pepper are piperine and various piperine isomers.[2] Piperine is concentrated in OR; however, it is possible for them to crystallize out. Therefore, it is important that suppliers manage these variables to suspend or dissolve the crystals. Piperine is much less pungent than capsaicinoids—about 100,000 to 200,000 SHU when purified.[4] Like chili peppers, the pungent principles of black pepper and ginger are non-volatile and concentrated in the OR, not the essential oils.

The pungent principle of fresh ginger (*Zingiber officinale*) is gingerol, coming in at about 80,000 SHU. Dehydration of ginger creates derivatives of gingerol called shogaols, which are hotter than gingerol, at about 160,000 SHU. Heating of ginger may create hydrogenation products such as zingerone, which at 50,000 SHU, is not very pungent.[4]

Thiocyanates are a different type of pungent compound. They are mainly perceived as nasal irritants. Examples include allyl isothiocyanate found in mustard (*Brassica nigra*), and allyl and phenethyl isothiocyanate in horseradish (*Armoracia lapathifolia*). These volatiles compounds can be found in the essential oils.[3]

Products tested **T-1**

Product	Kalsec code*	Pungency principles (sensates)
OR Black pepper	03.01	Piperine
OR Capsicum (oil-soluble)	01.050.03.601	Capsaicins
OR Capsicum (water-dispersible)	01.050.00.606	Capsaicins
OR Ginger	13.01	Gingerol, shogaols, zingerone
Oil of mustard	58.03	Isothiocyanates
Oil of horseradish	22.887607	Isothiocyanates

*Kalsec codes correspond to commercially available products at specific dilutions used to generate the results presented in this article.

Materials and Methods

Selection of pungent extracts: Commercial OR and essential oil products were selected for profiling. These included capsicum extracts (**see T-1**), both OR and water-dispersible (WD); black pepper OR; ginger OR; mustard oil; and horseradish oil. As commercial products, they are standardized with carriers and essential oils and may have added surfactants for water solubility.

Base creation and dosing: A basic salsa recipe was prepared by a chef (**see formulation in T-2A**). Six different pungency extracts were added to the salsa and then evaluated by a trained sensory panel. Both WD and oil-soluble flavors dispersed well into the salsa base (**T-2B**).

The second application consisted of flavors being sprayed onto a retail baked snack cracker. The flavors were sprayed on with a fine-mist spray bottle. The oil-soluble flavors were diluted in oil; the WD flavors were diluted in water. The water dilution was slightly stronger, reducing the amount of topical spray on the crackers in order to avoid too much liquid being absorbed by the crackers (**T-2C**).

Sensory evaluation: Descriptive panelists (n=18) were trained on time intensity techniques as well as pungency rating and pungency sensation descriptions. Panelists were given coded samples and asked to rate the pungency over time (10 minutes). The panelists were given the direction to take a small bite every 15 seconds

for the first 2 minutes, rating the pungency every 30 seconds for the first 2 minutes, and for every minute for the remainder of the 10 minutes. This type of consumption and time intensity simulates real world consumption, where a consumer would eat more than a single bite. It allows for interpretation of what happens while the sample is being consumed, as well as residual aftertaste or pungency perception after consumption stops.

Time intensity: To determine the area under the curve, each time-intensity plot was fitted with a third-order quadratic equation. This equation was integrated, with the resulting equation used to calculate the area under the curve by solving for x=10 minutes.

To determine the T_{max} value, the derivate of the third-order quadratic equation was calculated. Setting the derivate equation to 0, the T_{max} was calculated using the quadratic formula. Using the calculated T_{max}, the intensity at T_{max} was calculated.

Tongue mapping: Panelists were asked to rate the intensity of pungency for specific locations on their tongue. Panelists were given a 3x3 grid, as shown in **Sensory Ballot and Tongue Map Grid**. At each time point, panelists rated the pungency using the tongue map, indicating the intensity and location on the tongue where pungency was perceived.

Basic salsa recipe **T-2A**

Salsa base	%
Canned whole tomatoes	92.75
Cilantro	0.85
Green bell pepper	5.80
Salt	0.60
	100.00

Results and Discussion

Time intensity: As shown in **F-1** and **F-2**, the time intensity profile was evaluated in both salsa and a snack cracker. Panelists sampled the products for the first 2 minutes, at which point nothing further was consumed. Most of the extracts evaluated show an increase in pungency while consumption is occurring, with a noticeable drop off as soon as panelists stopped eating. The only exception to this trend is that of black pepper OR, which either remained steady or continued to build in pungency after the 2-minute mark. This finding may be of interest to a product developer that is looking for a sensation that gets hotter over time.

The time intensity information for snack crackers and salsa is shown in **T-3** and **T-4**. It is important to remember that the sample was consumed every 15 seconds for a total of 2 minutes. The T_{max} value represents the length of time to get to the maximum intensity, which was calculated based on the quadratic equation, rather than estimated from the data set. This value allows a product developer to understand how long it takes before the maximum pungency perception is reached. In both the snack crackers and salsa, black pepper had the highest T_{max} value.

The ratio of the intensity of T_0 to T_{max} is shown, which allows a product developer to understand the increase in pungency that will occur over time. One interesting trend to note is the higher ratio of T_0 to T_{max} for all spices in salsa, as compared to snack crackers. In comparing capsicum samples for a salsa, the ratio of initial heat to maximum heat is approximately 60–80%. In a snack cracker, however, this ratio is much lower, approximately 20–25%. What does this mean for a product developer? If the project is a dry snack food, expect a large increase in pungency over time. When formulating a pungent wet sauce, such as salsa, the heat will release as soon as the sample is consumed.

Salsas dosed with pungent extracts **T-2B**

	WD Capsicum	OR Capsicum	Oil of horseradish	OR Ginger	OR Black pepper	Oil of mustard
Salsa base	99.99	99.99	99.80	99.90	99.80	99.80
Extract	0.01	0.01	0.20	0.10	0.20	0.20
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Crackers dosed with pungent extracts **T-2C**

	WD Capsicum	OR Capsicum	Oil of horseradish	OR Ginger	OR Black pepper	Oil of mustard
Cracker	98.04	98.36	97.00	97.00	97.00	97.00
Extract	0.10	0.08	0.30	0.30	0.30	0.30
Water	1.86	-	-	-	-	-
Canola oil	-	1.56	2.70	2.70	2.70	2.70
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Sensory Ballot and Tongue Map Grid

Time Intensity—Heat in Salsa

Name_____

Panelist number_____

You will be given three samples. Taste a bite every 15 seconds for the first 2 minutes. Rate the heat for every time point listed for a full 10 minutes. Also, show the place on your tongue that is affected, and rate the intensity. Please describe the sensation, by circling the sensations listed. Also, if you detect a specific spice or flavor, please list that in the space provided.

Sample 312	Initial heat	30 sec	60 sec	90 sec	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Overall heat													
	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue	Back of throat Tip of tongue
Sensation	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus	Numbing Tingling Cooling Sinus
Spice or flavor detected													

Time intensity data for snack crackers **T-3**

Formulation	Intensity at T_0	T_{max}	Intensity at T_{max}	Ratio T_0 to T_{max}	Intensity at $T_{10\ min}$	Area under the curve
OR Capsicum	2.0	2.9	10.0	0.20	3.1	66.9
WD Capsicum	2.2	3.0	8.8	0.25	2.2	59.4
OR Black pepper	0.8	3.7	7.8	0.10	3.3	56.7
OR Ginger	1.1	2.8	5.8	0.19	0.8	34.4
Mustard	0.7	1.8	2.3	0.30	0.0	9.8
Horseradish	0.5	1.9	2.0	0.25	0.2	9.4

Time intensity data for salsa **T-4**

Formulation	Intensity at T_0	T_{max}	Intensity at T_{max}	Ratio T_0 to T_{max}	Intensity at $T_{10\ min}$	Area under the curve
OR Capsicum	6.3	2.2	8.2	0.77	2.5	59.6
WD Capsicum	5.4	2.4	8.8	0.61	2.6	61.1
OR Black pepper	2.5	3.4	6.7	0.37	2.9	50.9
OR Ginger	4.3	2.4	7.0	0.61	1.6	46.7
Mustard	2.2	1.5	4.3	0.51	0.2	16.9
Horseradish	2.7	1.4	5.3	0.51	0.4	21.3

The residual pungency after 10 minutes is also listed. This is important for understanding how long a consumer will be "on fire" after they stop eating. Black pepper, the late bloomer in the bunch featuring the lowest T_0 to T_{max} ratio, showed the highest pungency after 10 minutes. Heat builds slowly and lasts longer, for a slow, long-lasting burn. Contrast this with horseradish and mustard, which have a fast heat that does not linger, and ginger which expresses a heat profile lying between capsicum and mustard/horseradish.

The area under the curve (AUC) is shown as an aid for overall pungency perception. For example, WD capsicum and OR black pepper show similar AUC values. This value should not be used as the sole indicator for pungency perception. As discussed earlier, the spices differ in the maximum intensity (higher for capsicum) and residual pungency at t = 10 minutes (higher for black pepper).

Panelists were also asked to describe the sensation perceived. This was presented as a simple "present" or "absent" option. The percentage of panelists who indicated the perception based on sensate is shown in **F-3** and **F-4**. One noteworthy observation was that the mustard and horseradish extracts were perceived as numbing, tingling and impacting within the sinus cavity. This work is in agreement with the published literature.[3] Another interesting observation was the slight cooling effect noted in ginger in the dry application by a small percentage of panelists.

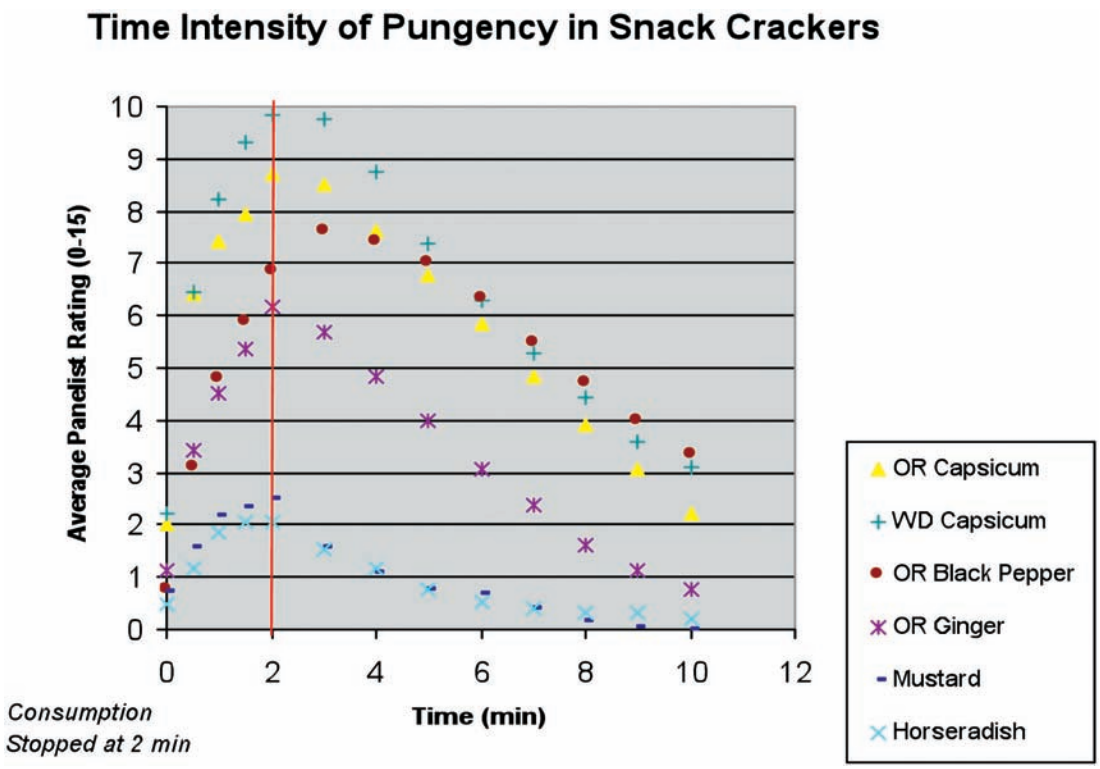
Tongue mapping: **F-5A** and **F-5B** (dry application) and **F-6A** and **F-6B** (wet application) show the perception of heat on the surface of the tongue over 6 minutes. The scale represents the percentage of overall heat that was perceived on specific locations on the tongue. Time at 0 minutes is the initial impact on the mouth. This is important to the product developer as the consumer will make up his or her mind whether to eat more after the first bite. Is it too hot? Not enough?

Time at 2 minutes is the end of the consumption. The level of heat is important as the consumer may stop eating after a certain level of heat builds in the mouth. Heat perception may determine total consumption. Time at 4 minutes reflects how much the heat lingers after eating. Do you want the consumer to have residual heat in his or her mouth after eating? Will this affect when the consumer will eat more?

In **F-5A** and **F-5B**, capsicum pungency at T = 0 minutes is predominately down the middle of the tongue. At the end consumption (T = 2 minutes), heat has built up all over the mouth, and remains that way at T = 4 minutes. In contrast, black pepper initial heat is hotter on the tip of the tongue, relative to the rest of the tongue. After 2 minutes, the heat is intensely perceived across the back of the tongue, and the lingering heat is still very hot and in the back of the mouth at T = 4 minutes.

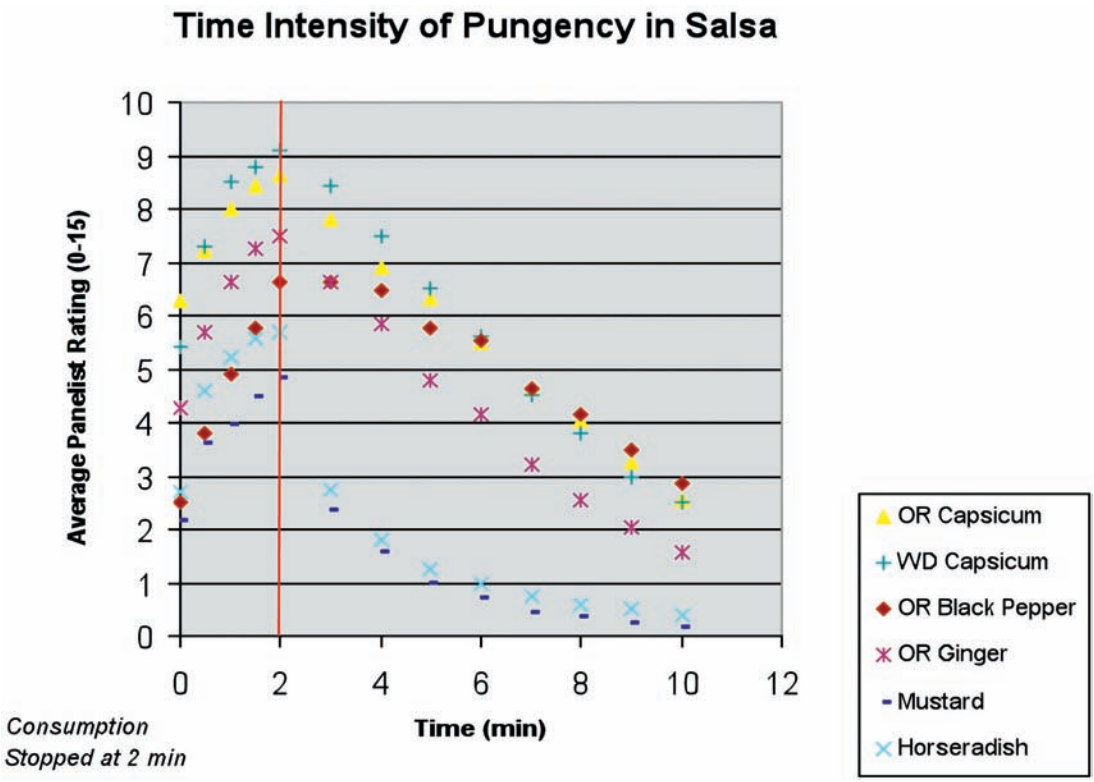
In **F-6A** and **F-6B**, capsicum heat in a wet application is initially more pronounced toward the back. At 2 minutes, the heat is all in the middle of the tongue (not so much on the sides) and very hot in the back. The lingering heat at 4 minutes is not as localized in the back of the tongue as at the end of consumption, but still over most of the tongue.

Pungency over time in snack crackers **F-1**



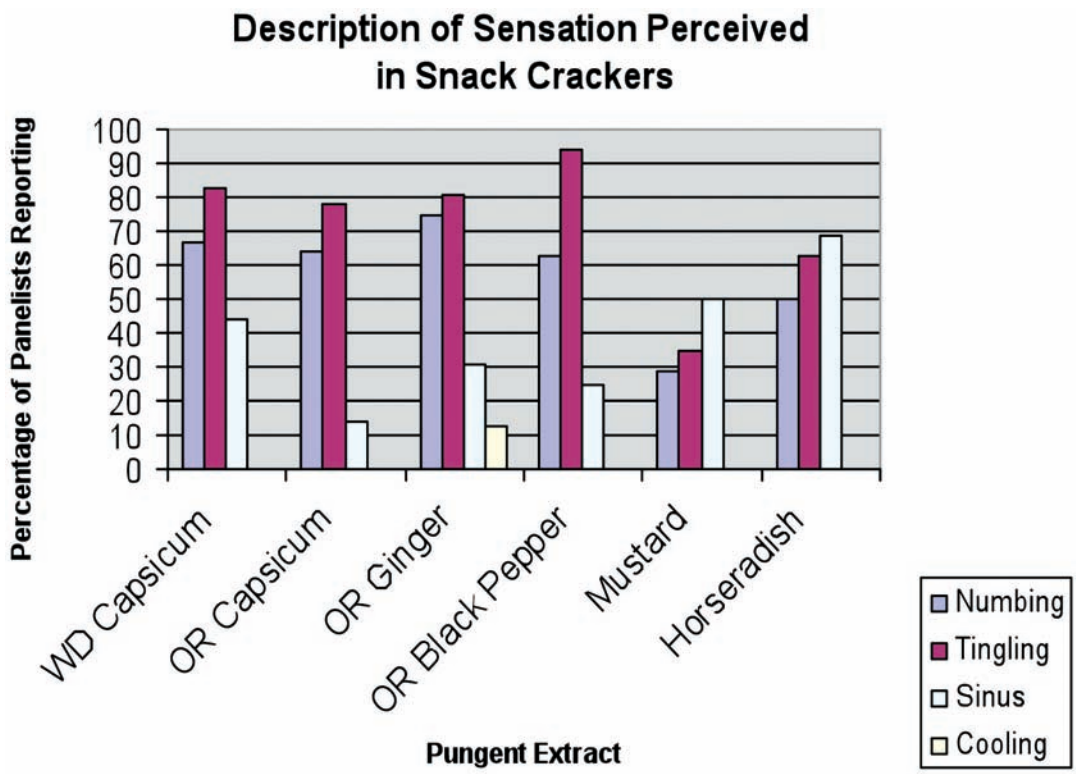
Pungency over time in salsa

F-2



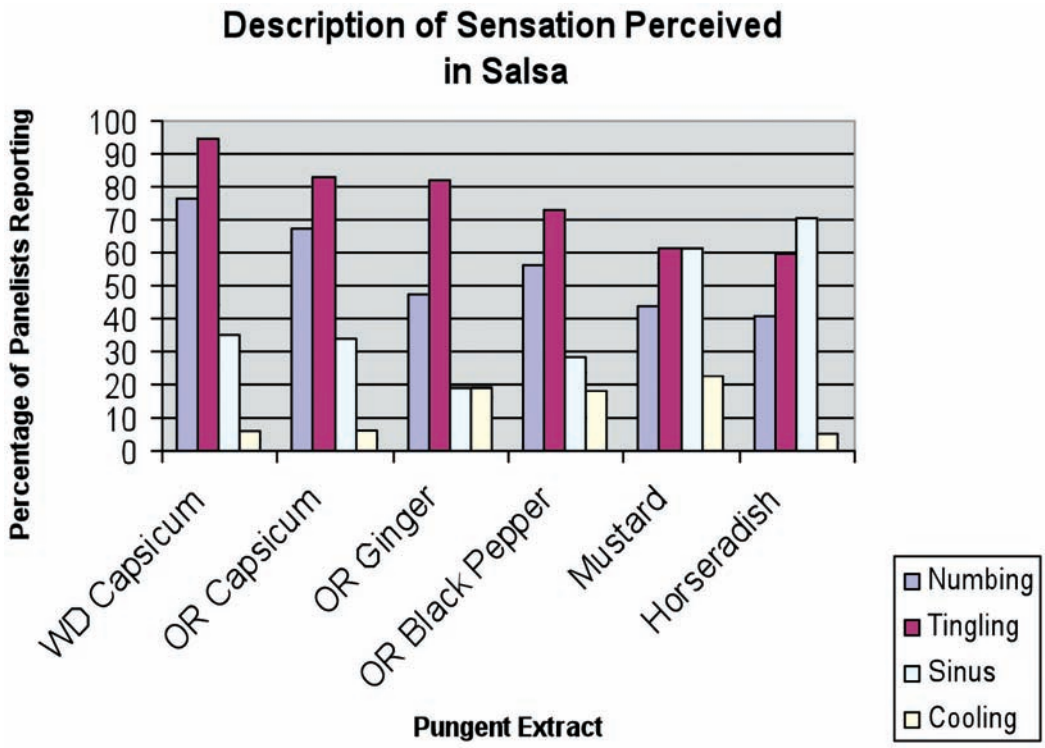
Perceived sensation in snack crackers

F-3



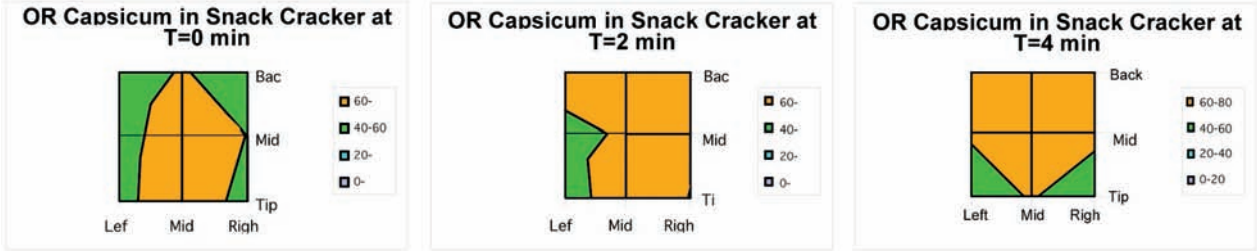
Perceived sensation in salsa

F-4



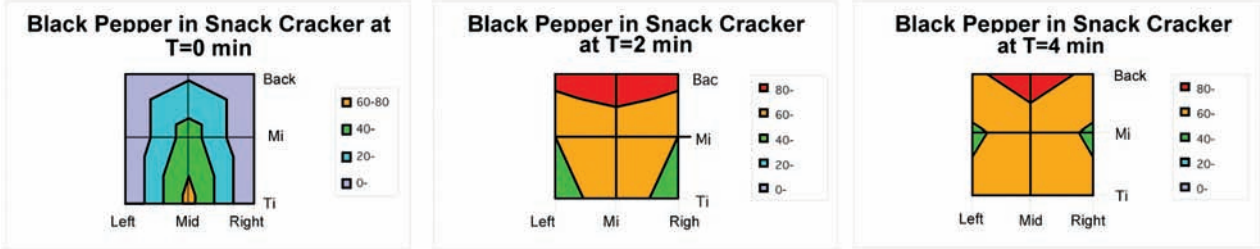
Tongue maps—capsicum in snack cracker over time

F-5A

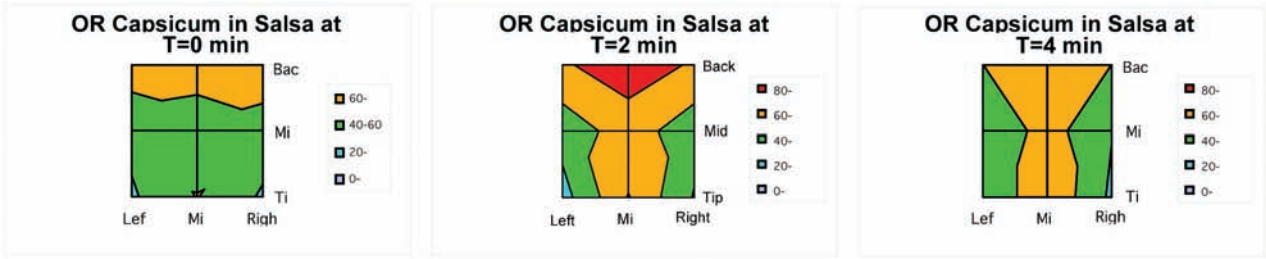


Tongue maps—black pepper in snack cracker over time

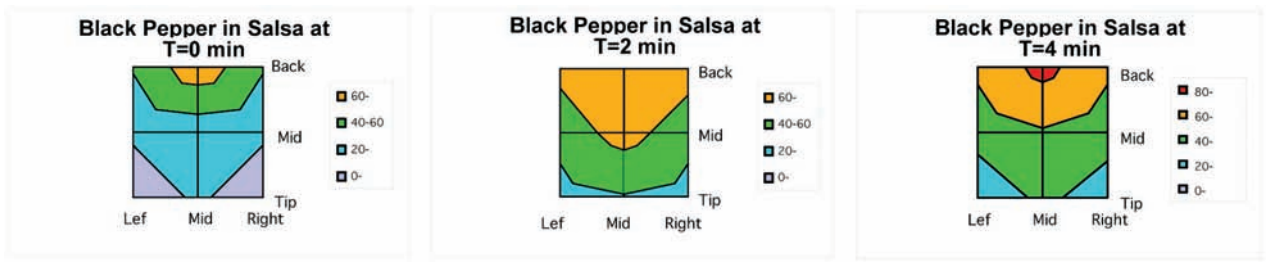
F-5B



Tongue maps—capsicum in salsa over time **F-6A**



Tongue maps—black pepper in salsa over time **F-6B**



The initial heat of the black pepper again is not as intense initially, but is hotter in the back of the tongue. With time, the heat continues to build in the back of the tongue and is actually hotter 2 minutes after consumption stops.

Conclusion

Understanding the product developer's project and desired time intensity profile is the first step in selecting the proper source of pungency. When trying to select the right pungency for application, there are a few things to consider, including when the heat should be registered—immediately, building during chewing or after swallowing. If a heat that responds immediately and slowly fades is desired, capsicum is likely the best choice. If a heat that hits the back of the throat and strengthens after swallowing is needed, black pepper would be preferred. If a heat that is tantalizing to the sinuses, responds fast and fades immediately is required, then the best choice is horseradish or mustard. A heat that steadily increases and fades, finishing with a slight cooling sensation, requires ginger. Options exist in natural pungent extracts through a range of quick intense heat to slow, gradual heat.

Acknowledgements

The authors thank the sensory staff and panelists at Kalsec for preparing and evaluating the products. They also thank Gretchen Rustenholtz for assistance with calculations and general support.

Address correspondence to Shane McDonald, Kalsec, Inc., 3713 West Main St., Kalamazoo, MI 49005; smcdonald@kalsec.com.

References

1. F Katz, Hot, cool, and bubbly, *Food Processing, www.foodprocessing.com/articles/2005/293.html* (2005)
2. G Reineccius, An overview of flavor perception, In: *Flavor chemistry and technology*. 2nd ed, CRC Press, Boca Raton, Florida (2006)
3. F Whitfield and J Last, Vegetables, In: *Volatile compounds in foods and beverages*. H Maarse, ed, Marcel Dekker Inc, New York (1991) 203
4. H Richard, Spice and condiments I, In: *Volatile compounds in foods and beverages*. H Maarse, ed, Marcel Dekker Inc, New York (1991) 411