The science behind almond pairings

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THE FLAVOR INTELLIGENCE COMPANY

Almonds are consumed all around the world, from the United States to India. They are consumed as a healthy snack, parts of delicious desserts or eaten in further processed forms such as almond butter or almond milk.

Over 80% of the world's almonds are grown in California which is the only place in North America that grows almonds for commercial purpose. Furthermore, almonds are found to be used more frequently as an ingredient in snack food products than other nuts.
It is of key importance to R&D departments to understand WHY this difference exists. Therefore, The Almond Board of California joint forces with Foodpairing® to understand the science behind the success of almond pairings.

The report will provide a closer look into the aroma profile of raw, blanched and roasted almonds to unlock their unique pairing potential and provide inspiration for future applications. Special attention will be given to two Californian varieties: '*Nonpareil*' *and* '*Monterey*'.

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Popularity of almonds as an ingredient

Almonds are available in different forms, raw, blanched, roasted as well as processed in slices or powdered into flour. They can be sprinkled over one's breakfast, -a yoghurt bowl with fruits and nuts is a classic example - and ice cream, - almond slices sprinkled on top of a banana split. Or even onto some savory dishes, such as on Moroccan chicken, lemon tajine or Indian Mughlai curry (a spicy chicken curry). These nuts are also suitable for vegan diets as milk substitutions, in gluten-free diets as alternative flours and as sauce thickeners in buttery form.

Almond butter is a spread similar to peanut butter that can be consumed by those looking for a milder flavor and is rich in natural sweetener. Almond orgeat syrup is used in fancy cocktails, such as Mai Tai (a rum cocktail with a delicious blend of almond, lime, and tropical fruit flavors).
Also, almonds are rich in fatty acids, which makes them suitable for extracting almond oil to use in salads and dressings.
Almonds are the base ingredients for marzipan and are key in nougats (pure or flavored with chocolate, orange, berries, honey), cookies (macarons de Paris or Israeli tahini cookie) and cakes, giving them all a unique taste.

Now that we know the wide variety of applications for almonds, we set out to investigate the science behind them in order to unlock its pairing potential for new product development and enable consumers to taste and experience almonds versatility.

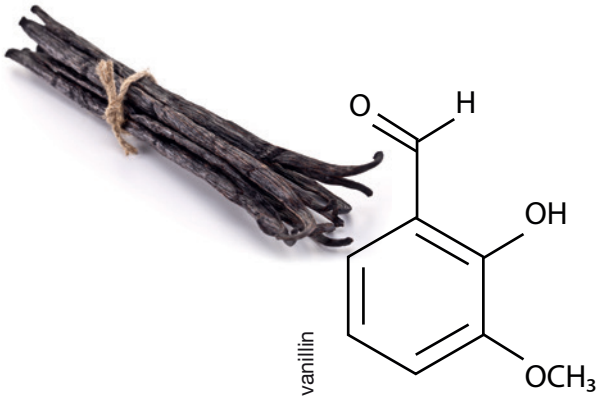
Aroma

A smell is very important for our flavor experience and food enjoyment. In fact, it is much more important than the actual taste in our eating experience. How important aroma is for the total flavor experience will vary from product to product. Generally we can say that **50% to 80%** of the flavor is determined by the aroma.

If you try to look up on how almonds actually taste, you may find lots of descriptors being used - they may use words such as nutty, almond, benzaldehyde, fruity, dried fruit, beany, sweet, caramellic, or even unpleasant woody - depending on who is tasting them, what kind of tasting experience they have and how sensitive they are to tastes and aromas.

However, there is no such thing as a chocolate fragrance. The **aroma** of chocolate consists of various aroma molecules in a certain concentration. Some food products have a more complex composition than others.

In some limited number of cases, aroma molecules can drive the aroma of a product e.g. vanillin in vanilla, benzaldehyde in almond. These molecules are very often associated with the ingredient. If you smell a sample of these aroma molecules you would immediately recognize a certain ingredient.

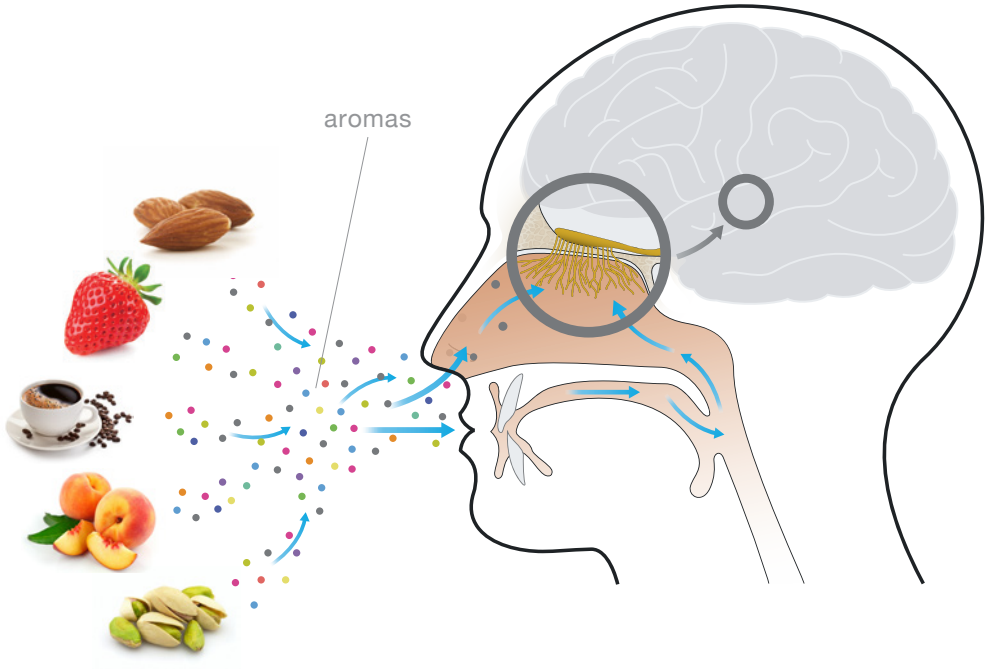


To experience the importance of smell you can try following test: cut yourself a piece of chocolate, pinch your nose and bite into it. Can you describe what you have just tasted? Probably a bit of sweet and bitter taste but not much else. Now take another bite, this time without pinching your nose. You should taste the same bitterness, but now with the added burst of chocolaty flavor – or rather, fragrance.
This is what we mean by the full flavor experience.

An **aroma molecule** can be any volatile organic compound (VOC) that has a smell and vaporizes easily. There are over ten thousand different VOCs that have been identified in food. However an aroma molecule has to reach a certain **odor threshold** (concentration level) in a specific ingredient to be perceived by humans. Aroma molecules reach our sense of smell through the air we inhale. We perceive aromas both through the nose, orthonasal, and through the mouth, retronasal. Through enhancing interactions, some aromas that are below this threshold do generate a detectable smell.

In practice, only a fraction of the VOCs are really responsible for the aroma profile of the ingredient. These **key odorants** are present in concentrations that exceed the odor recognition threshold. Dark Chocolate, for example, contains 1500 different VOCs that can be easily detected by a gas chromatography coupled mass spectrometry (GC-MS) equipment, but only 50 to 90 of these molecules are actually responsible for the strong chocolate flavor including nutty, spicy and caramellic notes as well as some fruity and floral hints.

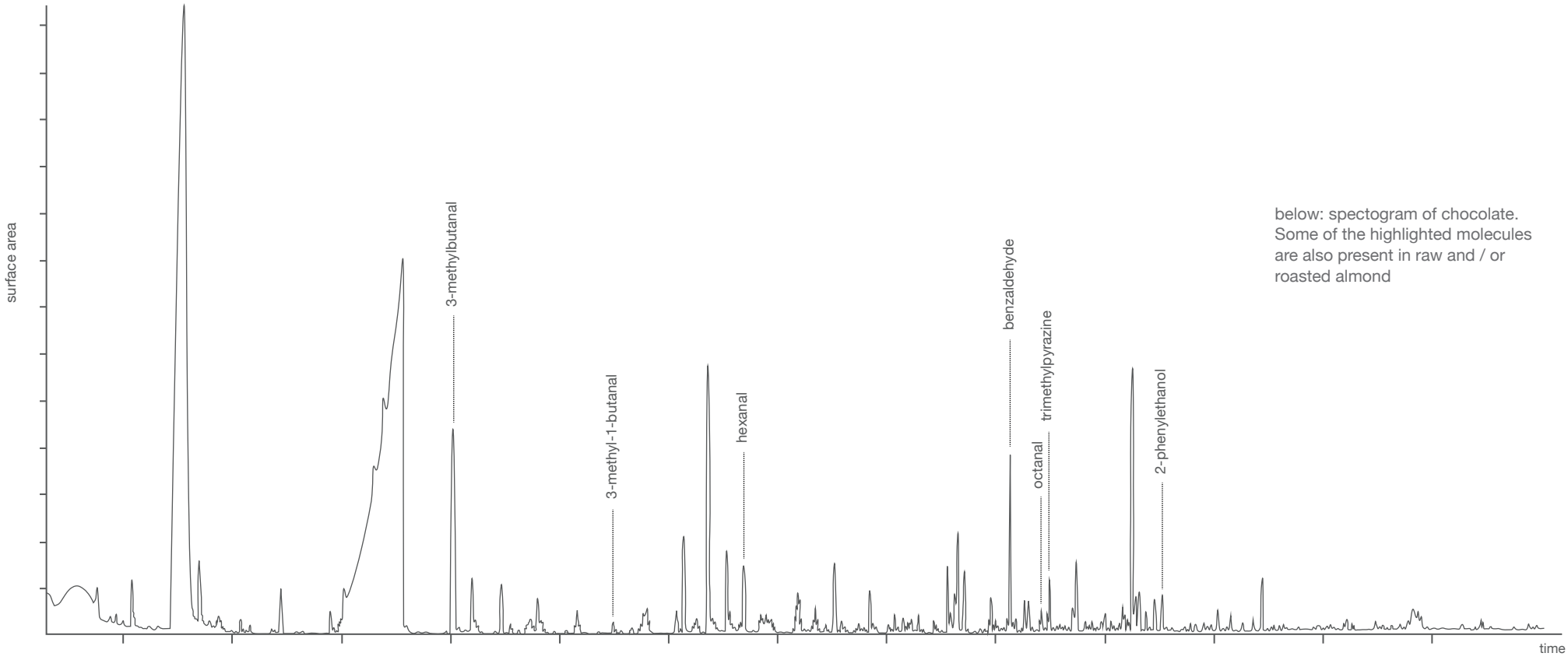
Foodpairing® developed a methodology to understand the ingredients' aroma profile to identify aroma synergies and create new flavor combinations.



The science behind Foodpairing®

To understand the aroma profile and be able to calculate new pairing possibilities, Foodpairing® starts with a **GC-MS based analysis.** A dissolved sample of the ingredient is fed into the gas chromatograph, which vaporizes and separates the individual substances as they pass from the coiled column into the mass spectrometer. Depending on their individual molecular properties and weight, the compounds travel at varying speeds through the spectrometer's detector. We then record the retention time for each molecule.

At first glance, these odorants are just a bunch of peaks in a spectrogram, something that is hard to work with, especially for someone who does not see such data on a daily basis. To make it more understandable, Foodpairing® created aroma types and aroma descriptors. The VOCs are translated into standard aroma types and aroma descriptors, which are applied to all **3000+** ingredients in the Foodpairing® database.
This **classification procedure** is a **unique method** developed by Foodpairing®.



below: spectogram of chocolate. Some of the highlighted molecules are also present in raw and / or roasted almond

Aroma profile

An **aroma profile** visualizes the aroma types and the aroma descriptors. The aroma profiles are built up of some of the 14 main aroma types, e.g. fruity, which are further divided into a total of 70 aroma descriptors, such as fruity-coconut.

The translation into **aroma types** and aromadescriptors were determined by Foodpairing® by plotting all of the aroma molecules in a 3D web and observing their similarities. This made it possible to group every aroma molecule into 14 main aroma types. To further divide these aroma types, taking into consideration the base scents of each aroma molecule, we created the term '**aroma descriptors**'. Each aroma descriptor belongs to an aroma type.

This classification is used to create a visual presentation of the aroma profile of an ingredient, an aroma wheel. The wheel consists of two circles: an inner circle displaying the present aroma types and a broken outer circle indicating the concentration of the available aroma descriptors. The length or height of each colored part indicates the concentration of each aroma type and descriptor.

This aroma profile is then used to determine which flavor combinations, pairings, would work well together, in what ways the variety of almonds are different from each other and how this distinctiveness is reflected in potential pairings.

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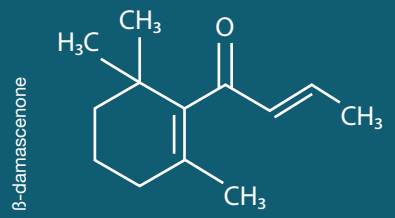
Every aroma molecule has its own distinct base smell, which can change according to its concentration in a certain product.

ß-damascenone for example has a flowery-rose base scent, but by changing its concentration, the scent changes from a more floral to a more fruity-apple-like fragrance in apple to more the scent of cooked apple (as in beer) and to that of the baked apple.

In some products, it can even have a fruity-peach-like or honey-like smell.
Although ß-damascenone has a range of different scents, it was cataloged, based on its base scent, under floral - rose.

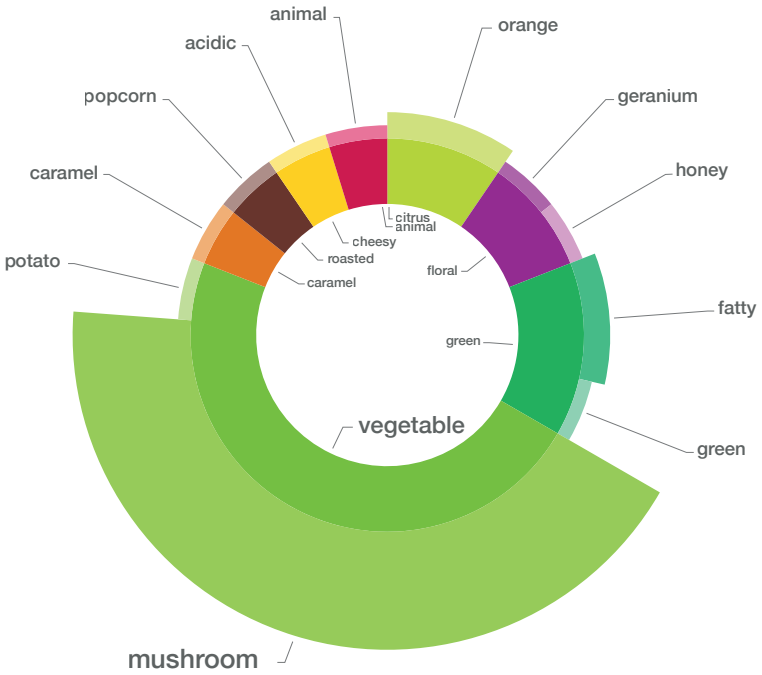


What is the Impact of processing on the aroma profile of almonds?

Raw & blanched almonds

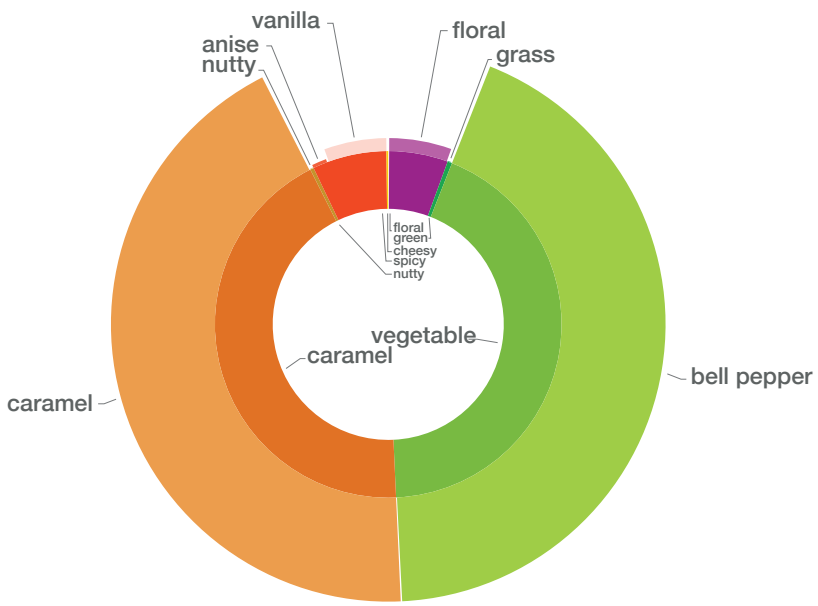
From the moment almonds are harvested, their aroma profile undergoes a transformation. The fruits are shaken onto the ground, where they dry naturally. After harvest, almonds go to a huller/sheller facility where the nuts pass through a roller to remove the hull, shell and any debris from the orchard, such as sticks and rocks. Then, almonds are separated based on their sizes and stored. To produce blanched almonds the brown seed coat is also removed.

If we now zoom in on the aroma profile of blanched almonds, it may be surprising to find a high concentration of vegetable-smelling aromas.
This is attributed to the treatment with warm water that softens the seed coat so that it can be easily removed. This process evoques some chemical reactions giving the almonds these vegetable notes, smelling like mushrooms and cooked potatoes, as well as some roasted popcorn-like and caramellic notes. Other green (smelling green, fatty-like), floral (smelling like geranium and honey), citrus (orange-like), cheesy - acidic-like molecules complete the profile of blanched almonds.

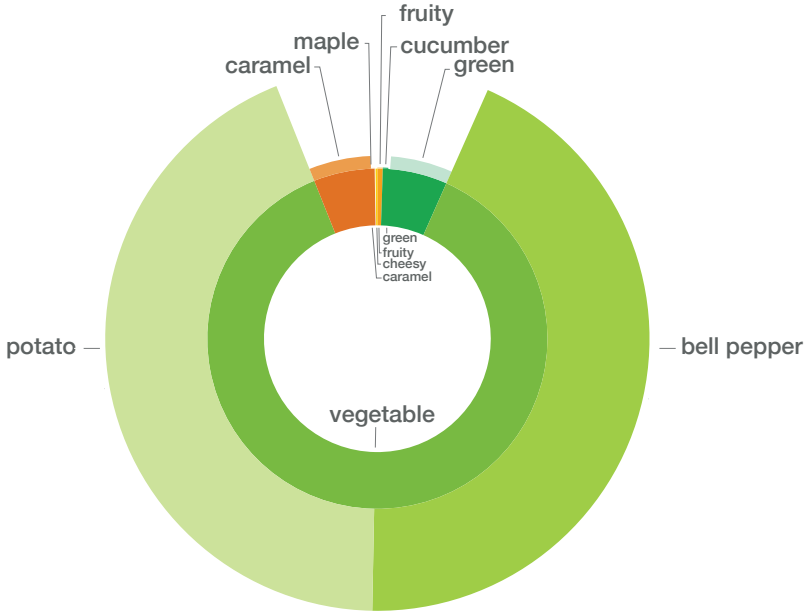


Unlike the blanched almonds, the raw almonds contain a high amount of pyrazines. These pyrazines are key for the aroma of bell pepper, chili peppers, peas, green beans, fava beans, all kinds of legumes like soybean, mung bean, black turtle beans and even baked potato. However in almonds they have a greener more earthy, nutty-like smell.

In all analyzed samples the raw almonds, caramellic, floral, green, roasted and cheesy notes are present. The roasted popcorn-like molecules give a nuttier sense, whilst they also have more fruity- and spicy (vanilla, anise-like) aroma molecules, which adds some extra pairing options to the already extensive pairing palette.



Monterey



Nonpareil

Roasted almonds

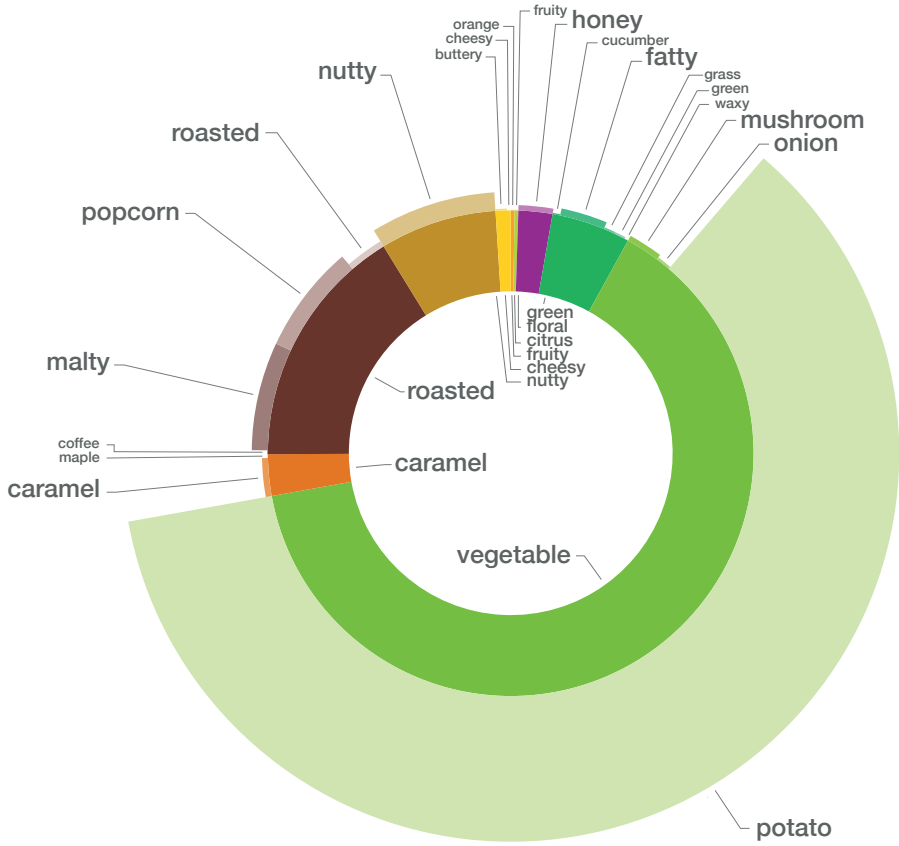
In identifying potential flavor combinations, it is important to take into account the aromatic differences between whole natural, and roasted almonds. These differences influence the nature of new applications of the almonds and therefore result in various pairing possibilities.

Specifically, when roasting almonds the composition of the aroma profile changes due to chemical reactions such as the Maillard reaction, the Strecker degradation and caramelization. Several new molecules are created while for other molecules present in raw or blanched almonds the concentrations change.

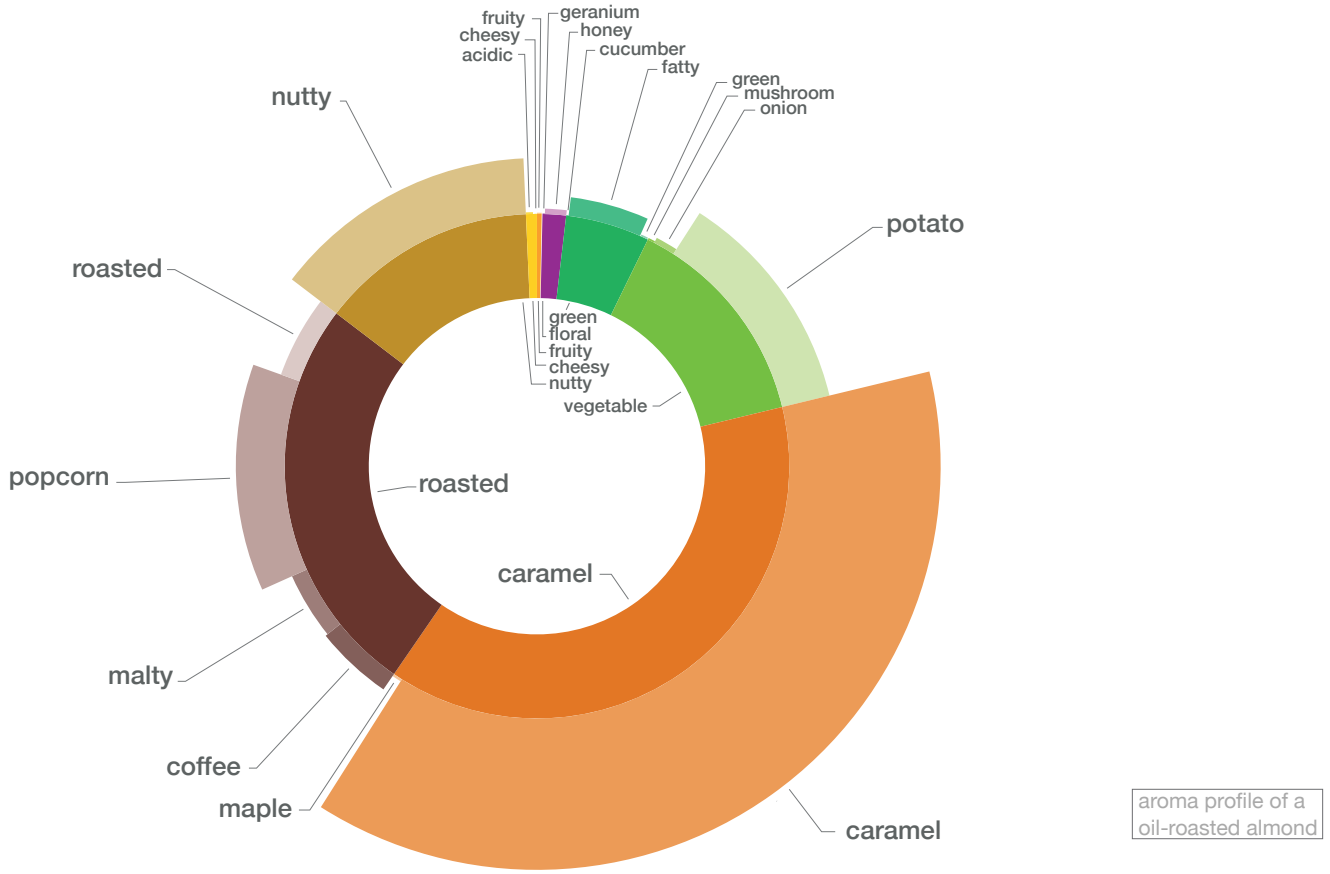
The **Maillard reaction** occurs when sugars and proteins react with one another when heat is applied. The reaction occurs at a temperature of 140 to 165 °C (280 to 330 °F) which results in non-enzymatic browning. This creates roasted, nutty and popcorn flavors.

Through the **Strecker degradation**, proteins are converted into fragrant aldehydes such as methional (potato-like), phenylacetaldehyde (floral-honey-like) and 3 methylbutanal (roasted-, malty-, chocolate-like). These aldehydes can degrade again to form new molecules, e.g. methional can degrade to sulfurous aroma molecules having a more onion, garlic-like smell.

Caramelization is a reaction where sugars form more complex polymers and emit caramellic and maple syrup-like aromas.



It also makes a difference whether almonds are dry-roasted or **oil-roasted**. The profile of oil-roasted almonds is influenced by the oil: extra molecules are formed, the higher temperature of the oil causes more degradation of the sugars (more caramellic notes), and more Maillard reactions occur (more roasted and nutty notes).



aroma profile of a oil-roasted almond

As a result of such reactions, profiles get more roasted, nutty, caramellic and vegetable -potato-like notes. Therefore roasted almonds pair much better with ingredients that also have undergone these reactions. Think of pan-fried or roasted meat or fish, meat stews like the Moroccan tajine, and ingredients like Iberico ham, chocolate, coffee and bread.

"Benzaldehyde, having a distinct almond scent, is one of the key molecules for the almond flavor. When almonds are roasted, the concentration of benzaldehyde rises. At very high temperatures (e.g. oil roasted almond) this concentration decreases again, but still remains above the threshold. Due to the formation of pyrazines with a nutty-like smell, the overall flavor of oil-roasted almonds is nuttier than the dry-roasted almonds.

Due to the presence of benzaldehyde you can combine almonds with chocolate, cocoa powder, fruits like cherry, peach, apricot, apple, plum, and dried meats like Iberico ham and Parma ham".

Comparing different aromas

When examining the two Californian almond varieties: 'Nonpareil' and 'Monterey', more in detail, some differences in the unroasted aroma profile are observed.

- The 'Nonpareil' almond has a more generic nutty scent.
- The 'Monterey' almond has a more distinctive almond flavor (the concentration of benzaldehyde is just above threshold). The 'Monterey' almond has the most pronounced almond aroma, giving it a fruitier character than the other variety. Benzaldehyde also has some fruity, cherry-like nuances which are enhanced by the presence of 4-methoxybenzaldehyde, which has an anise-like scent with some fruity/berry-like nuances. Possible pairings include linden honey, red cabbage, red sweet potato, pan-fried nopales, cooked parsley root, blueberry and madras curry.
- The floral notes in the Monterey cultivar are very noticeable. The latter pairs well with cassia, baguette, dark chocolate, Sichuan pepper, wheat bread and acacia honey.

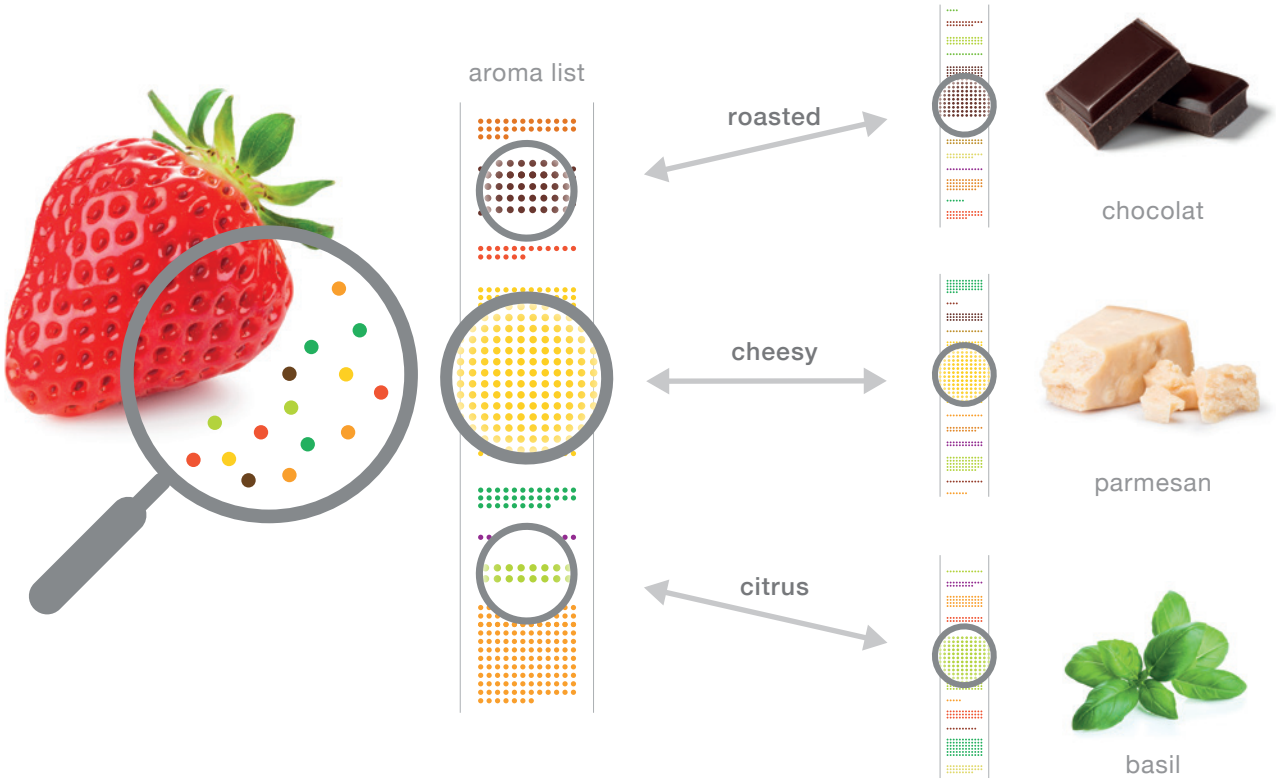
The 'Monterey' almond has a more complex and intense aroma profile. A more complex and intense aroma profile usually results in more matching ingredients and a wider variety of potential pairings.

Ingredients match when they share key aromas

By understanding the aroma of an ingredient, we can suggest flavor combinations, classic ones and new, surprising ones. To be able to calculate these combinations, we first need to determine the key odorants of the analyzed ingredients. Key odorants are present in concentrations that exceed the odor recognition threshold and therefore recognizable by humans. Once this is determined, an algorithm calculates which combinations can be made with the analyzed product, taking into account which key odorants they have in common.

‘Monterey’ almond pairs wonderful with toast bread, elderberry juice, lavender honey and Bayonne ham.
The ‘Nonpareil’ almond, on the other hand, combines well with dried beef, coffee, pan-fried wild duck, cooked butternut squash and cucumber.

By looking at consumer behavior and using data science, combinations of almonds in different applications and their popularity can be examined. When this research is combined with the pairing potential of each analyzed almond variety, the best potential pairing for certain ingredients in a certain application can be determined.



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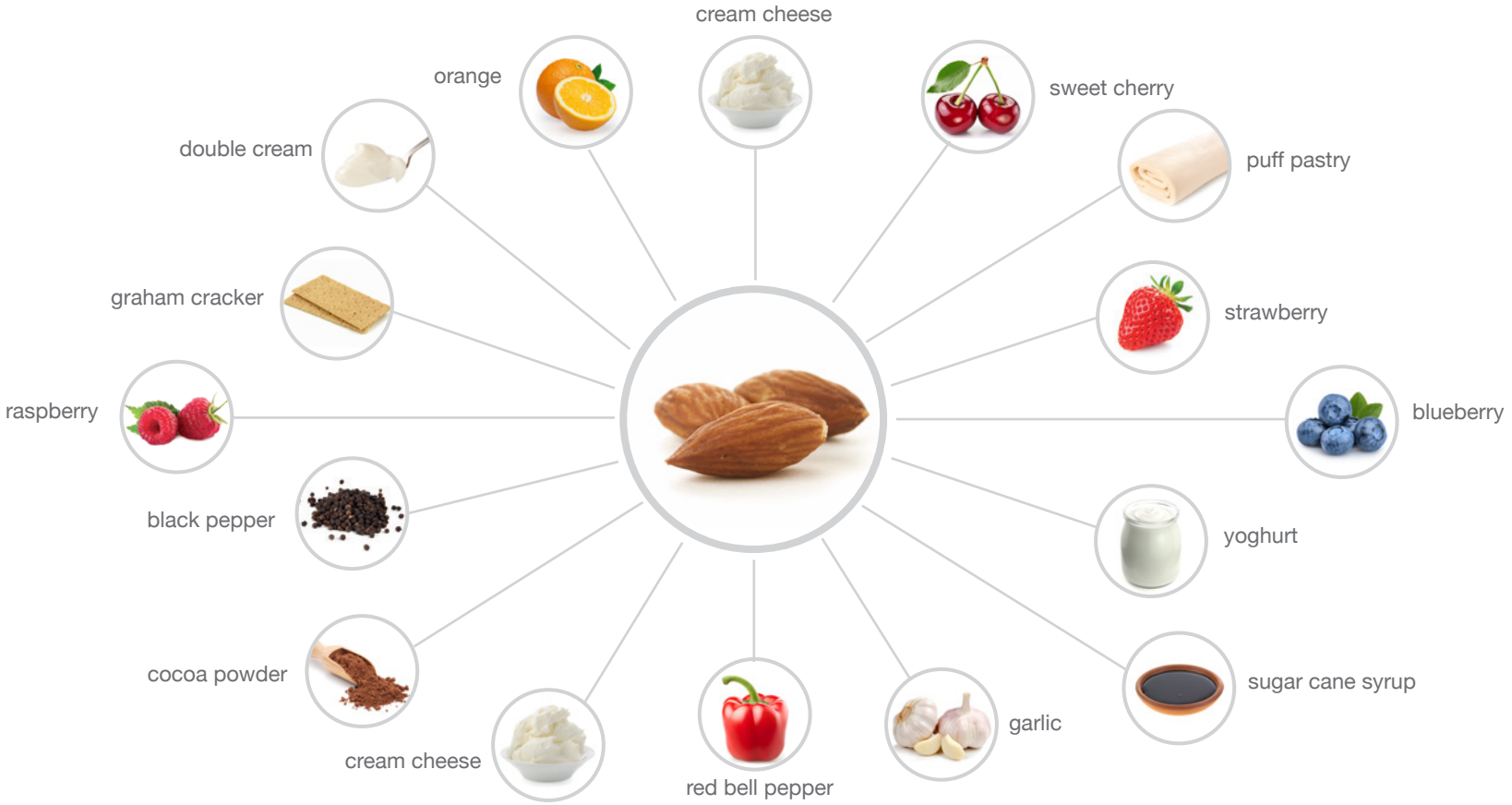
Nonpareil

Mix the roasted ‘Nonpareil’ almonds with citrusy herbs and spices or use the raw ones in combination with exotic fruits, roasted nuts, condensed milk, dulce de leche or cinnamon.

Raw:

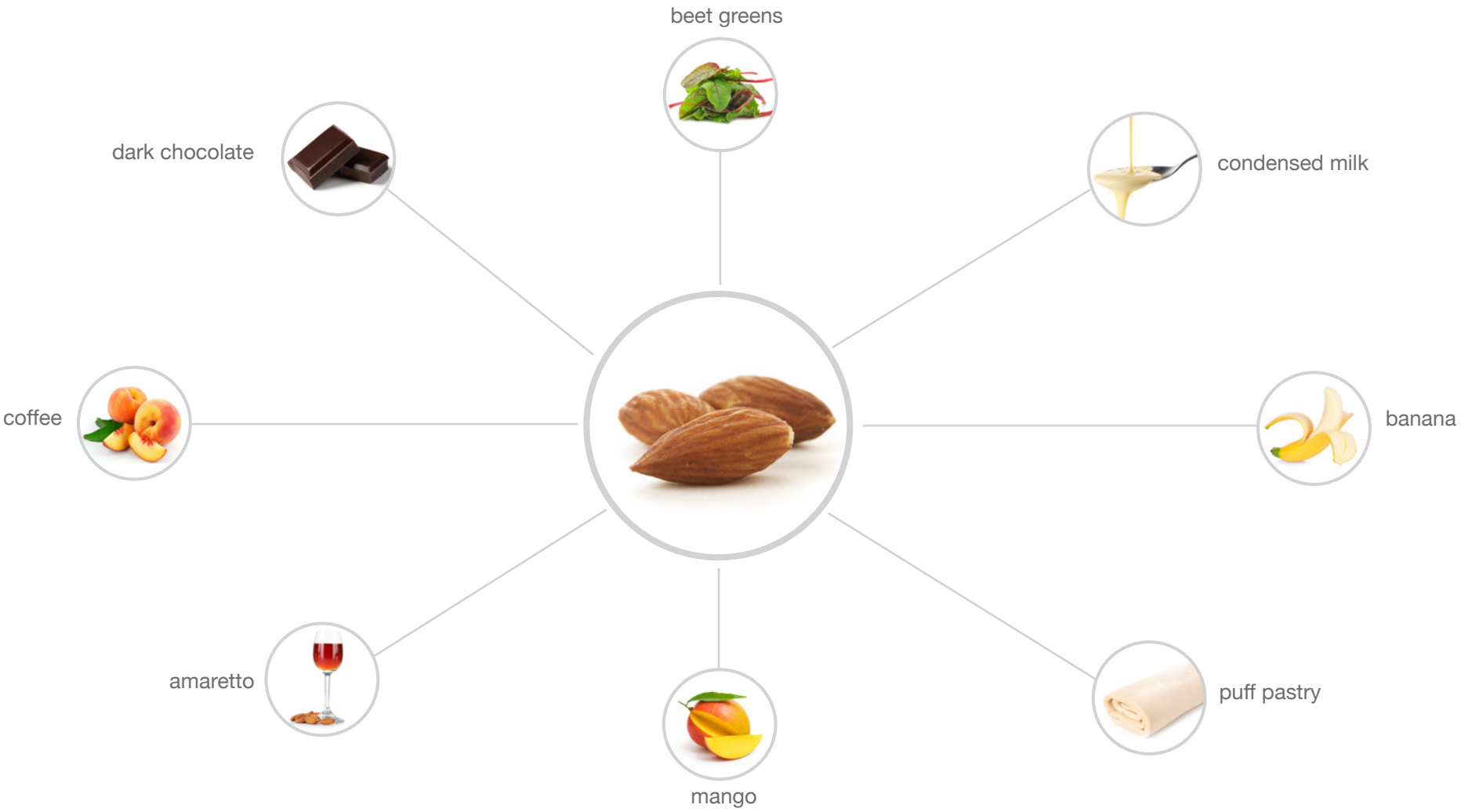
- bakery and pastry, cakes, muffins & cupcakes, cookies & biscuits, dips & spreads, on the go beverages, dairy & non dairy applications
- double cheese, graham cracker, raspberry, black pepper, cocoa powder, cream cheese, red bell peppers, garlic, sugar cane syrup, yoghurt, blueberries, strawberries, puff pastry, sweet cherry, cream cheese, orange



*Across all applications, best matching ingredients with specific variety and preparation method of almond

Roasted:

- on the go beverages, dairy & non dairy applications
- dark chocolate, beet greens, condensed milk, bananas, puff pastry, mango, amaretto, coffee



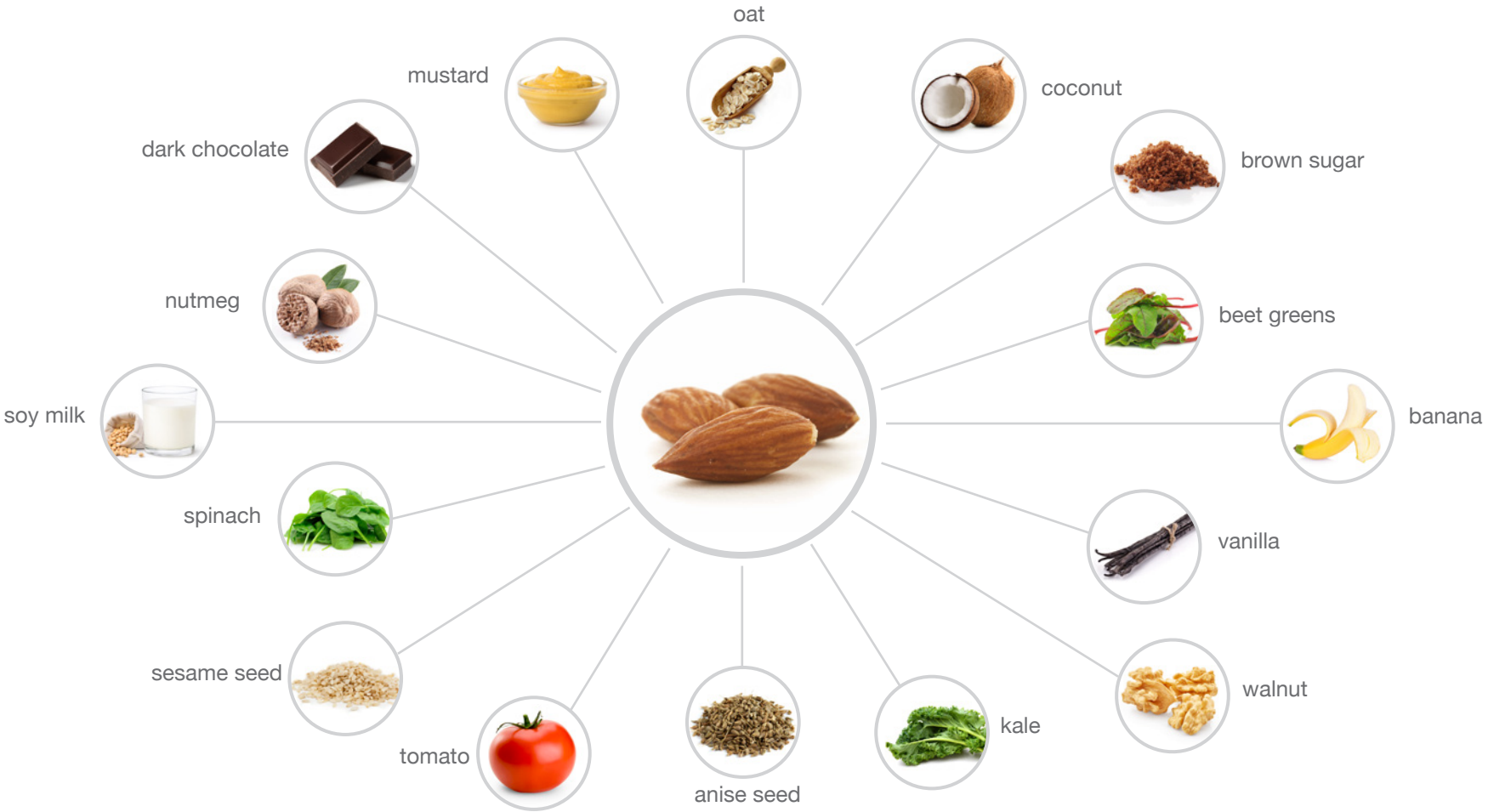
*Across all applications, best matching ingredients with specific variety and preparation method of almond

Monterey

Pair the ‘Monterey’ almonds with Tahitian vanilla, chocolate and nuts.

Raw:

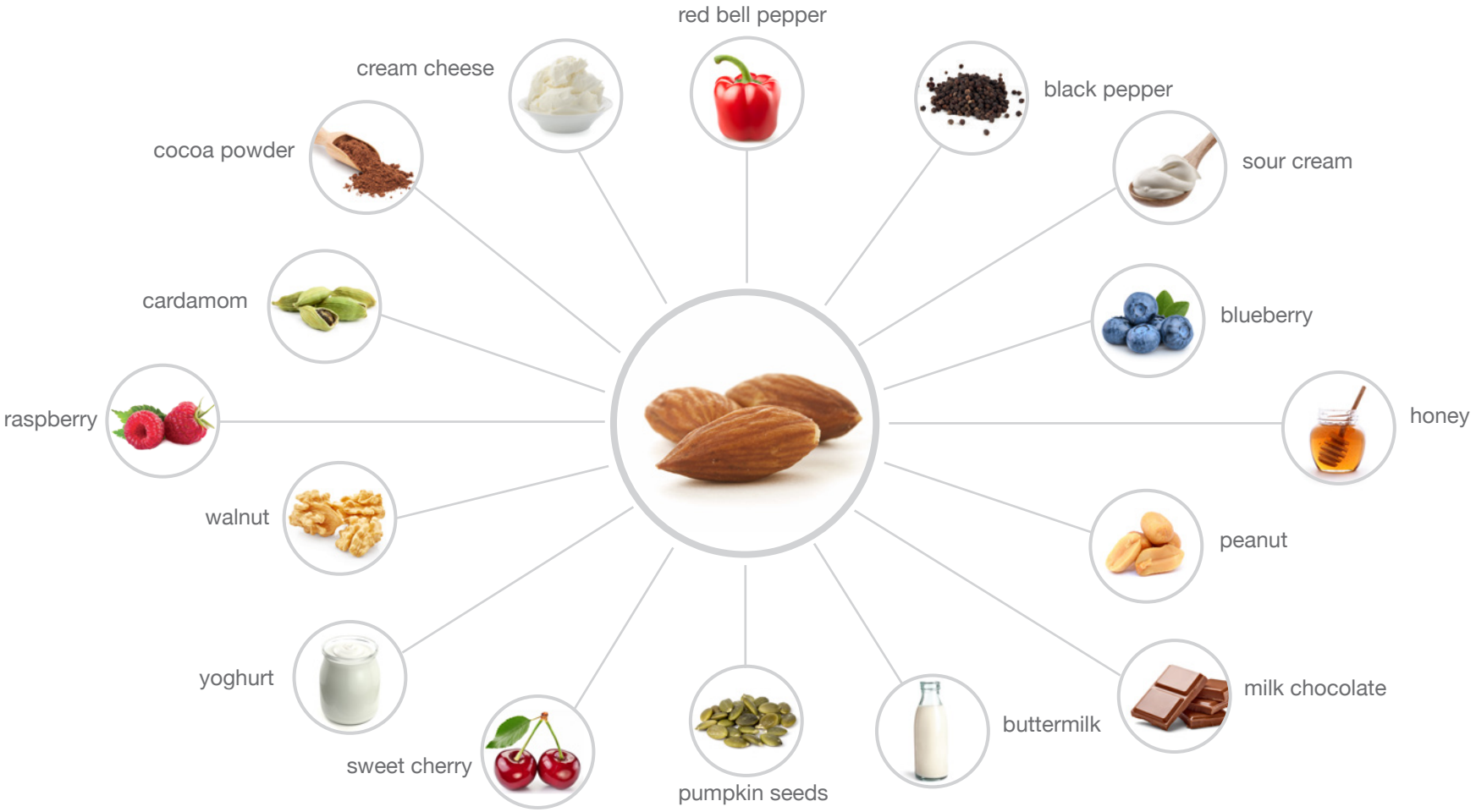
- cereal bar & granola, bakery and pastry, cakes, muffins & cupcakes, cookies & biscuits, confectionary, on the go beverages, dairy & non dairy applications
- oat, coconut, brown sugar, beet greens, bananas, vanilla, walnut, kale, anise seed, tomato, sesame seed, spinach, soy milk, nutmeg, dark chocolate, mustard



*Across all applications, best matching ingredients with specific variety and preparation method of almond

Roasted:

- cereal bar & granola, bakery and pastry, cakes, muffins & cupcakes, cookies & biscuits, confectionary, dips & spreads, on the go beverages, dairy & non dairy applications
- red bell pepper, black pepper, sour cream, blueberry, honey, peanut, milk chocolate, buttermilk, pumpkin seeds, sweet cherry, yoghurt, walnut, raspberry, cardamom, cocoa powder, cream cheese



*Across all applications, best matching ingredients with specific variety and preparation method of almond

Which type of almond should I use in my application?

The graph below, highlights which of the examined Californian almonds are best used in certain food applications.

	RAW		ROASTED	
	Nonpareil	Monterey	Nonpareil	Monterey
Cereal bar & granola		■		■
Bakery & pastry	■	■		■
Cakes, muffins & cupcakes	■	■		■
Cookies & biscuits	■	■		■
Confectionary		■		■
Dips & spreads	■			■
On the go beverages	■	■	■	■
Dairy & non dairy	■	■	■	■

Conclusion

Due to their diverse aroma molecules, almonds are often used in a large variety of applications, from desserts to savory dishes, or even spreads and dips. They can be eaten all day: for breakfast in smoothies, as a snack in their plain roasted form, as toppings on a savory lunch or as a midnight treat present in a nougat.

Our goal was to understand the complexity of almonds, the ways we can use them, the common and extreme pairings and the fields in which they can best be applied. Almonds are characterized by their versatile texture and complex aroma profile, which makes them perfectly suitable for many different applications.

The Californian almonds, contrary to other types, contain pyrazines which gives them a bell pepper note. Therefore these can be combined with ingredients that have a beany flavor profile, such as peas, bell peppers, baked potatoes and other legumes. The 'Monterey' variety is the most accessible almond to use within different applications due to its more complex and diverse aroma profile.

We have shown that almonds bring a nutty flavor, natural sweetness and texture to any dish or product. Now it is your turn to try these exciting and delicious new flavor combinations!

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