1. Phosphorus Concentrations in Environmental Samples

1.8 Plant and Animal Biomass

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1.8.1 Plants

Depending on their habitat the mean TP concentrations for terrestrial plants are 2 g kg^{-1} and for aquatic plants 6 g kg^{-1} (Lerch 1990) (Tab. 1.8-1). This can be attributed to the higher dry matter of terrestrial plants (more supporting tissue from cellulose and lignin) compared to aquatic plants (Duchesne & Larson 1989). Concentrations are also affected by external factors such as P availability in soil. Under favourable conditions, sunflowers accumulated 2.5 times more P in their leaves (up to 7.2 mmol TP m^{-2}) in comparison to half of the P availability (2.0 mmol TP m^{-2}, Jacob & Lowlor 1991). TP concentrations also depend on plant specific factors (e. g. plant species, genotype) and are organ-specific within the plant. For example, TP concentration in fine roots of copper beech was twice as high as in wood, bark and twigs (Lerch 1990). Plant age and season affect TP concentrations as well, since in different development stages different amounts of P are necessary (Wang et al. 2015, Saunders & Metson 1971).

Table 1.8-1 TP Concentrations in plant tissues and macro-algae (DM = dry matter)

Species or group	Tissue	influencing factors	TP (g kg^{-1} DM^{-1})	Reference
Terrestrial plants		Habitat, degree of organisation (supporting tissue)	0.5-8	Lerch (1991)
Aquatic plants			6	Lerch (1991)
Spruce (*Pinus sylvestris*)	Leaves	Species specific, normal nutrient supply	1.3-1.9	Mellert & Göttlein (2012)
Fir (***Picea abies***)			1.5-2.2	
Beech (*Fagus sylvatica*)			1.2-1.9	
Oak (*Quercus spp.*)			1.4-2.1	
Copper beech (*F. sylvatica*)	Fine roots	Different tissues	2.2	Lerch (1991)
	Wood		0.9	
	Bark		0.9	
	Twigs		0.9	
	leaves		1.3	

1.8.2 Animals

Similar to plants, the TP concentrations in animals depend on nutrition, tissue, ages and development stage. For a lot of vertebrates, and hence also for farm animals, especially the Ca:P ratio is important. For this reason, lots of studies demonstrate that P availability and feed utilization are affected by Ca concentration in feed (e.g. Song et al. 2017). On the one hand, P absorption can be inhibited by Ca, if slightly soluble Ca-phosphates are in the diet, which cannot be dissolved and adsorbed (Nakamura 1982). On the other hand, high P concentrations in feed can reduce Ca accumulation in bones (Masuyama et al. 2003). Song et al. (2017) demonstrated that activity of phosphatases in blood serum is a crucial factor for mineralisation of bones and accumulation of Ca and P in fish scales. In fishes the fish scales can be a sink for Ca and P, supporting Ca and P homoeostasis (Song et al. 2017, see table 1.8-3).

The way of life (herbivore/carnivore) and the feed availability depending on season (and therefore food sources) have an important impact on TP concentrations in animal bodies (Ghaddar & Saoud 2012). These authors documented highest TP concentration in muscular meat of white seabream in April but lowest in June (see table 1.8-2).This interrelation could be used to use special animals in special seasons for P poor diet of humans (e.g. some kidney diseases). TP concentrations vary especially with animal species (table 1.8-2) but also with tissues (blood, serum, muscles, bones).

Table 1.8-2 TP concentrations in animal tissues or serum (DM = dry matter)

Species or group	Tissue	Influencing factors	TP in tissues (g kg^{-1} DM^{-1})	TP in serum (g l^{-1})	Reference
Coral (*Lophelia pertusa*)	body	recent	0.016		Mason et al. (2011)
		fossil	0.123		
Rabbit fish *(Siganus rivulatus)*	flesh	herbivore	8.95		Ghaddar & Saoud (2012)
White sea-bream *(Diplodus sargus)*		carnivore	11.32		
Pheasant *(Phasianus colchicus)*	Pectoral muscle	Species specific	10.16		Straková et al. (2011)
Broiler	Pectoral muscle		9.25		
Cat	Muscle		10.5		Cuthbertson (1925)
Pig	Muscle		6.03		Jastrzębska et al. (2010)
Sheep Merino Landsheep	Muscle, ages	Mass: 18 kg	8.09		Bellof et al. (2006)
		55 kg	6.17		
Human	Muscle		1.56		Forbes et al. (1953)
Japanese seabass *(Lateolabrax japonicus)*	Serum	31 g Ca kg $feed^{-1}$		0.43	Song et al. (2012)
		4.2 g Ca kg $feed^{-1}$		0.31	
Human	Blood			0.36 - 0.43	Kay & Byrom (1927)

In humans high TP concentrations can be found in teeth and bones. According to Koolmann & Röhm (1998), the mean TP concentration in humans is 10 g kg^{-1} body mass and the daily TP demand is 0.8 g d^{-1}. Whereas in vertebrates high TP concentrations are in the endoskeleton, in invertebrates, such as mussels, gastropods and corals, most P is concentrated in the exoskeleton (table 1.8-3). For animals the growth stage is relevant for TP concentrations, for example lambs (German Merino Landsheep) have highest TP concentrations in early development stages, which decreases with development (Bellof et al. 2006). This decrease in TP concentrations can be attributed to the decrease in water concentrations in bone tissue during growth, which increases dry matter concentration in bones of older animals (Bellof et al. 2006).

Table 1.8-3 TP concentrations in animal skeletons (DM = dry matter)

Species or group	Suppor-ting tissue	Influen-cing factors	TP (g kg^{-1} DM^{-1})	Reference
Oyster (*Ostreidae*)	Shell		0.9	Yoon et al. (2003)
Snails (*Archachatina, Achatina spp.*)	Shell		10-69	Ademolu et al. (2016)
Japanese seabass (*Lateolabrax japonicus*)	Vertebrae	31 g Ca kg Futter^{-1}	125	Song et al. (2012)
	Scale		74	
	Vertebrae	4,2 g Ca kg Futter^{-1}	138	
	Scale		87	
Human	Teeth		125-137	Hennequin et al. (1994)
	dry, non-lipid bones		9.2-10	Zipkin et al. (1960)
	Bone ash		171-175	

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