4.3 Mechanical properties studies

4.3.1 Tensile Test

The analyses of the mechanical properties as a tool in the study of the behaviour of polymer biocomposites are of paramount importance. These analyses has been proved to be an effective method to study the behaviours of the composites under various condition of tension, compression, stress-strain, and phase composition of the fiber reinforced composites and its role in determining the strength of the biocomposites. The mechanical properties of these biocomposites depend on the nature of the polymer matrix, the structure and distribution of the reinforced fiber, and the nature of the interfacial adhesion between the different components in the composite. In this study, tensile testing was done to determine the mechanical strength of the PVA/starch and PVA/starch/fiber biocomposites. In tensile testing, the ability of a material to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in different applications. A comparison of the tensile strength, Young modulus, and percent elongation at break of the two different categories of biocomposites was done to determine its mechanical strength. Tensile strength and percent elongation at break represent the force per unit area required to tear the film and the ability of the film to stretch while Young modulus is a measure of the stiffness of a given material (Ramaraj, 2007).

PVA/starches composites

For the composite of PVA/starch, the tensile properties (tensile strength, young modulus and percent elongation at break) are shown in Figure 4.176, 4.177 and 4.178, respectively.

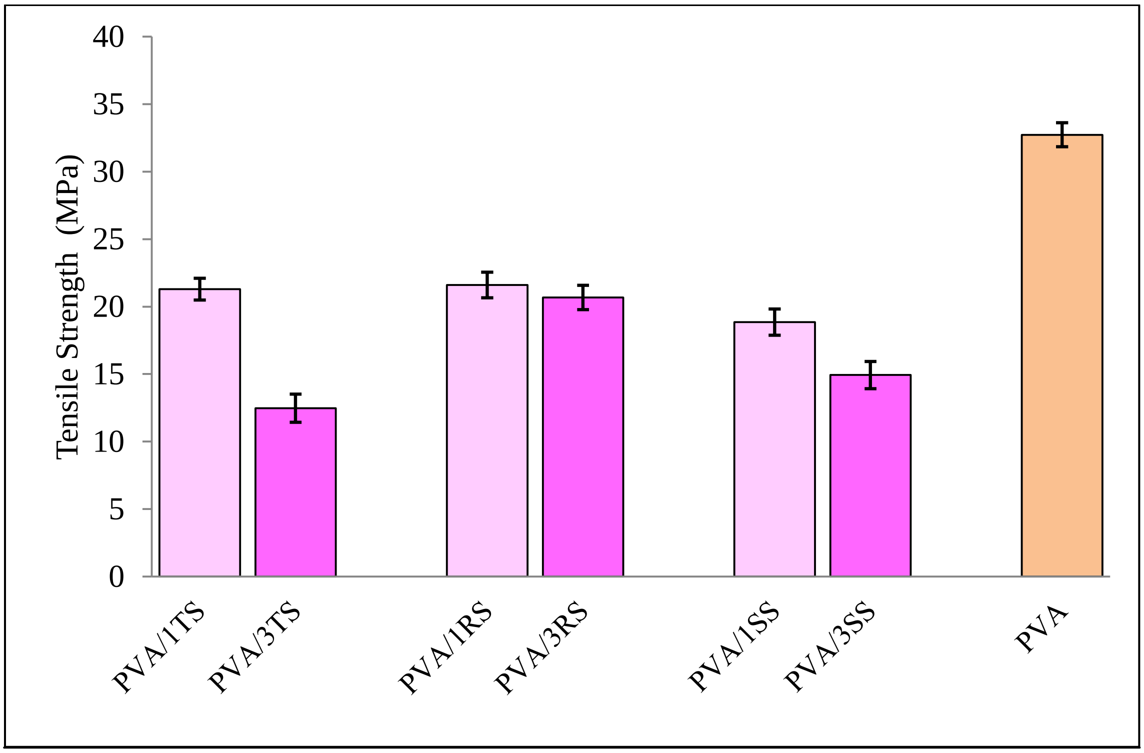

Fig. 4.176 Tensile strength values for PVA blended with different concentrations of different starches.

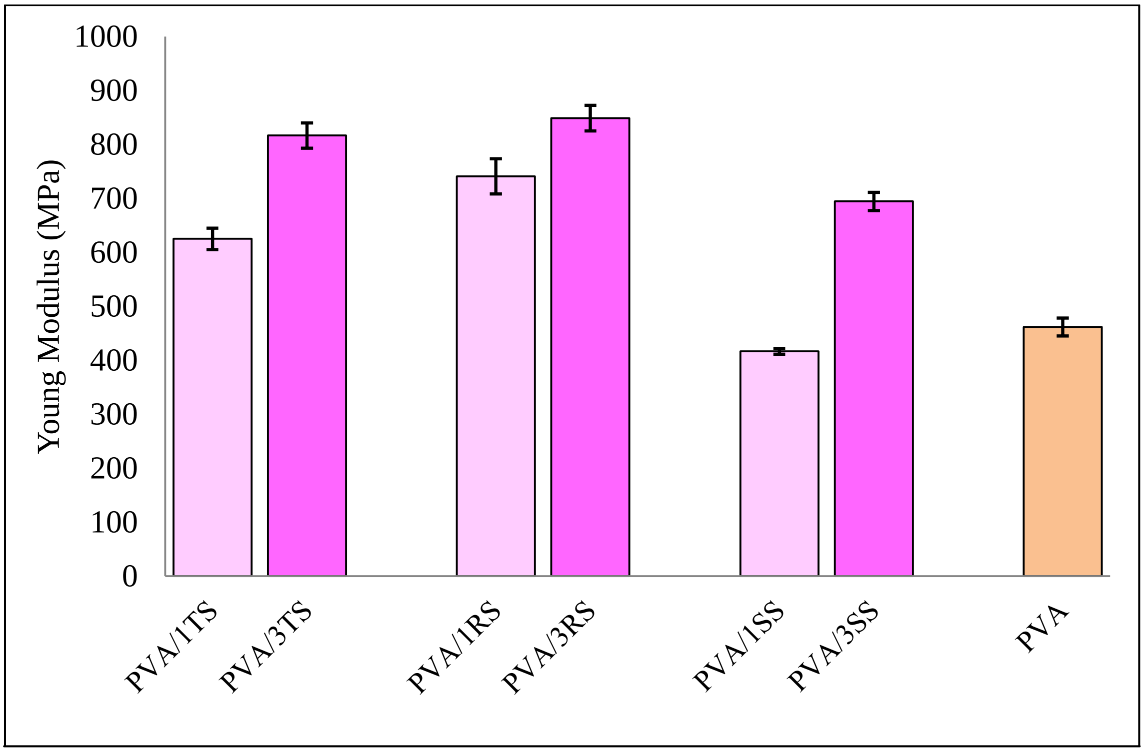

Fig. 4.177 Young modulus values for PVA blended with different concentrations of different starches.

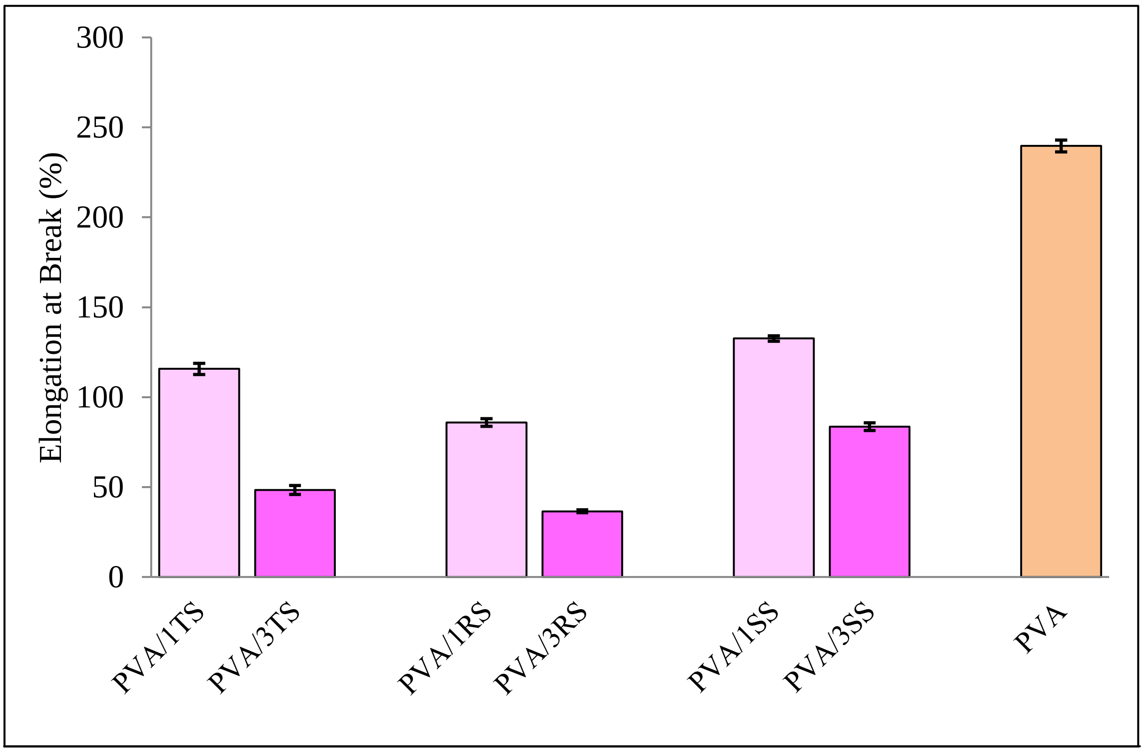

Fig. 4.178 Percent elongation at break values for PVA blended with different concentrations of different starches.

In general, comparison between the tensile strength values of pure PVA film and the composites of PVA blended with different concentrations of starches revealed that the blends exhibited a much lower value. The tensile strength of all the PVA/starch formulations decreased with increasing starch content, indicating that the starches that were incorporated behaved as non-reinforcing fillers. The tensile strength decreased between 36-48% and 40-62% in the blend of PVA containing 1 g and 3g of different starches, respectively. This result is in accordance with the tensile strength values reported by other researchers where the values of PVA/starch composite films were lower than that of pure PVA film, and decreases with increasing starch content (Ramaraj, 2007). A possible explanation for the decrease in tensile strength after the addition of starches into the PVA matrix could be the low interfacial interaction between the different components of the blended film, which would lead to lowering of the mechanical strength at the blends interface. The low tensile strength values also indicates that the addition of starches into the composite could not improve the mechanical properties of the composites because of the excellent mechanical properties of the PVA matrix itself and the poor compatibility of PVA and starch in nature (Chen, Cao, Chang, & Huneault, 2008) (Okaya, Kohno, Terada, Sato, Maruyama, & Yamauchi, 1992). Between the three blended composite, PVA/sago starch blend showed the lowest tensile strength values. The low tensile strength values obtained may be due to partial gelatinization of starch granules and the agglomeration of sago starches in the PVA/sago starch blend as may be observed in the SEM images of the blended film (Figure 4.50 and 4.51). When ungelatinized starch granules formed clusters or agglomerates, the agglomerations may not be fully covered by the PVA phase and this could eventually lead to the weakening of the interfacial adhesion between starch and the polymer matrix and lowering of the tensile properties. The composites of PVA blended with different starches also exhibited increasing Young modulus values as the concentration of starches in the composite increases. The moduli values of all the composites obtained were higher than the modulus of pure PVA film indicating that the blends become more rigid with the addition of the different starches. In general, the Young modulus is closely related to the rigid domains of the material (Jang, Huh, Jang, & Bae, 2001). The low moduli value of the PVA/sago starch composite may be due to lower rigidity of the composite film associated with the sago starch agglomerates as can be observed in the SEM images of the blended film.

As far as the starch proportion in the blends were concerned, it was found that percent elongation at break continuously decreased as the amount of starch in the polymer matrix increases. The addition of starch to PVA produced the general trend for filler effects on the polymer properties; i.e. the elongation decreased as the starch content increased due to the stiffening of the starch granules in the composites (St-Pierre, Favis, Ramsay, Ramsay, & Verhoogt, 1997). The decrease in the elongation can also be contributed by the weak interfacial interaction between starch and matrix. In polymer blends with ductile matrix such as PVA, the elongation at break is considered to be highly sensitive to the interfacial adhesiveness between the phases of the blend.

PVA/different starches/different fibers composites

For the composite of PVA blended with 1g of different starches and different concentrations of different fibers, the tensile strength values are shown in Figure 4.179, 4.180 and 4.181, respectively.

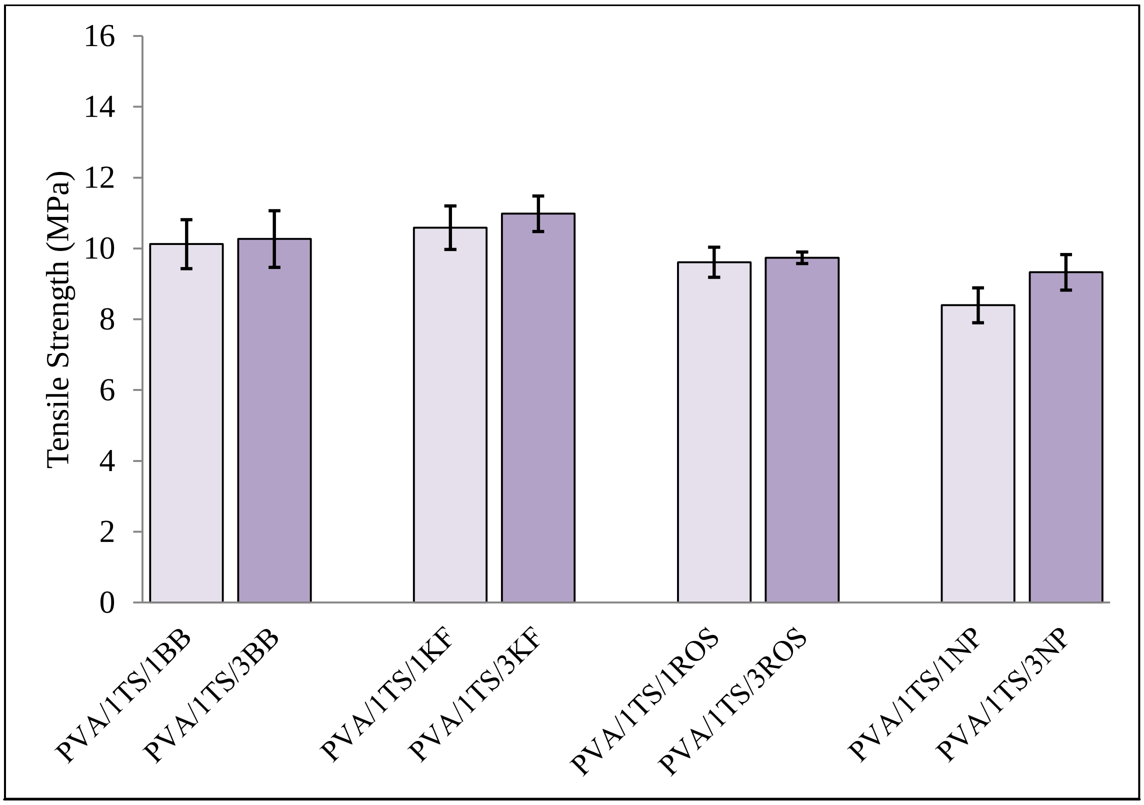

Fig. 4.179 Tensile strength values for PVA blended with 1g of tapioca starch and different concentrations of different fibers.

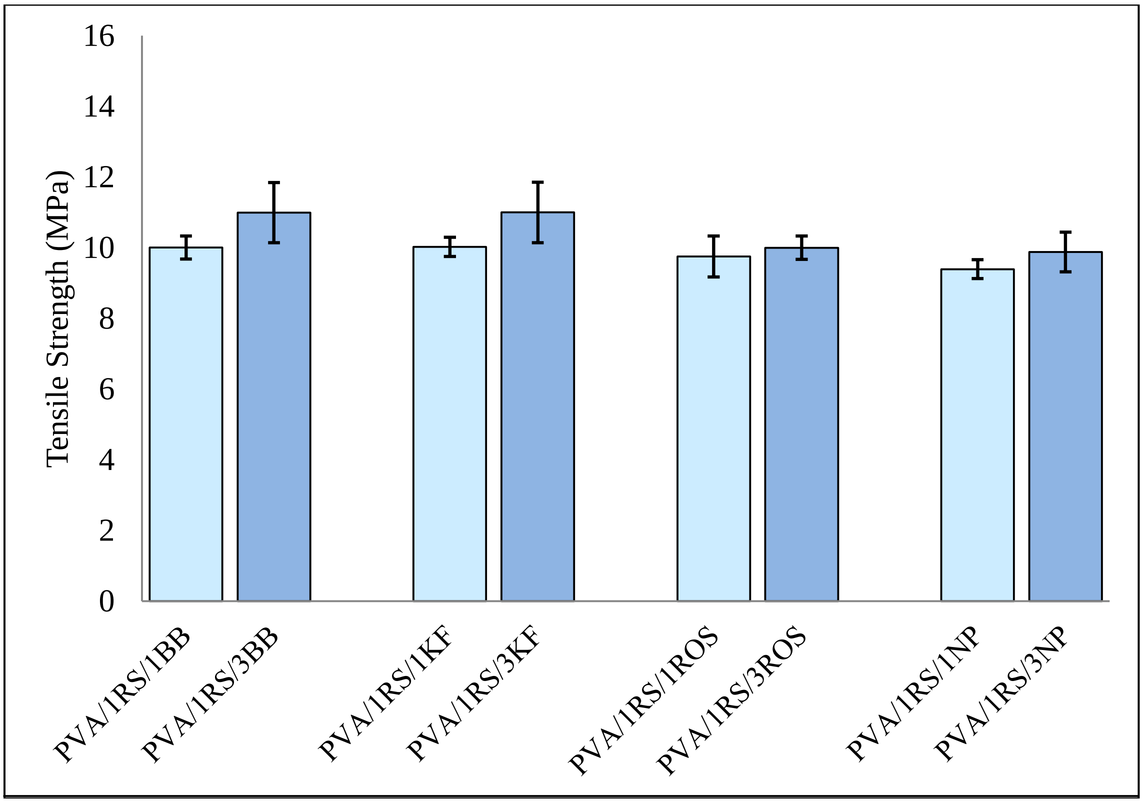

Fig. 4.180 Tensile strength values for PVA blended with 1 g of rice starch and different concentrations of different fibers.

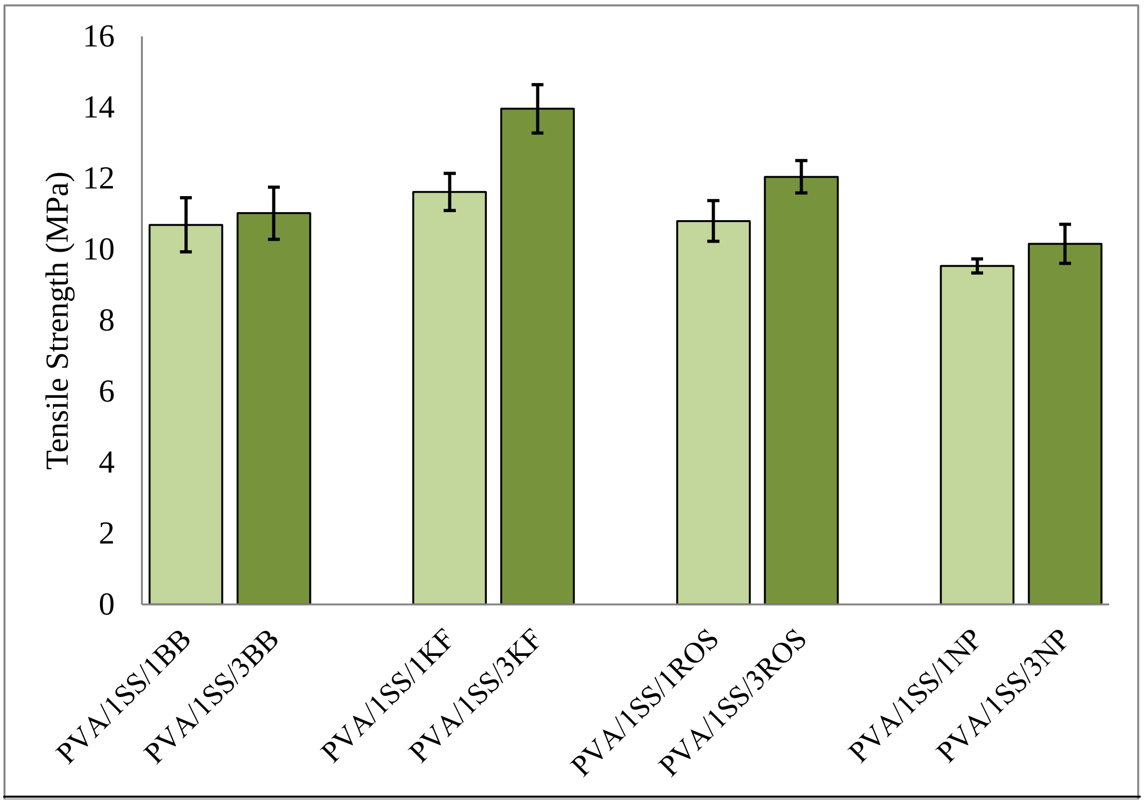

Fig. 4.181 Tensile strength values for PVA blended with 1g of sago starch and different concentrations of different fibers.

When different set of fibers were introduced into the PVA/starch matrix, the tensile strength as a whole for all of the blended films decreased when compared to the pure PVA films. Generally, from the charts, the values of the tensile strength of the PVA/starch/fiber composites were lower than the tensile strength values of the PVA/starch composites. The lowering of the tensile properties of the PVA/starch/fibers composites may be contributed by the non-uniformity of the incorporated fibers as can be observed from the SEM images (Figure 4.37 to 4.44). The non-uniformity of the fibers can contribute to poor interfacial adhesion between the fibers and PVA/starch matrix, which results in a less efficient stress transfer between matrix and fiber. Inefficient stress transfer between fibers and matrix will lead to breakage and rupture of the fibers during the mechanical testing. The loss of tensile strength in the composite may also be attributed by the phase separation between fibers and the continuous phase of the PVA/starch matrix. As for the PVA/starch composites, even though there were weak interactions between the interface of starches and PVA, the high content of PVA makes it the main load bearing phase in the composite and because of PVA continuous phase, the reduction in strength is only slight.

Comparison between the composites of PVA blended with different starches and fibers show that the PVA/sago/different fibers blends has the highest tensile strength even though its only a slight increase in the tensile strength value. Figure 4.182 and 4.183 show the tensile strength values of PVA/sago starch/different concentration of fibers as compared with the other composites.

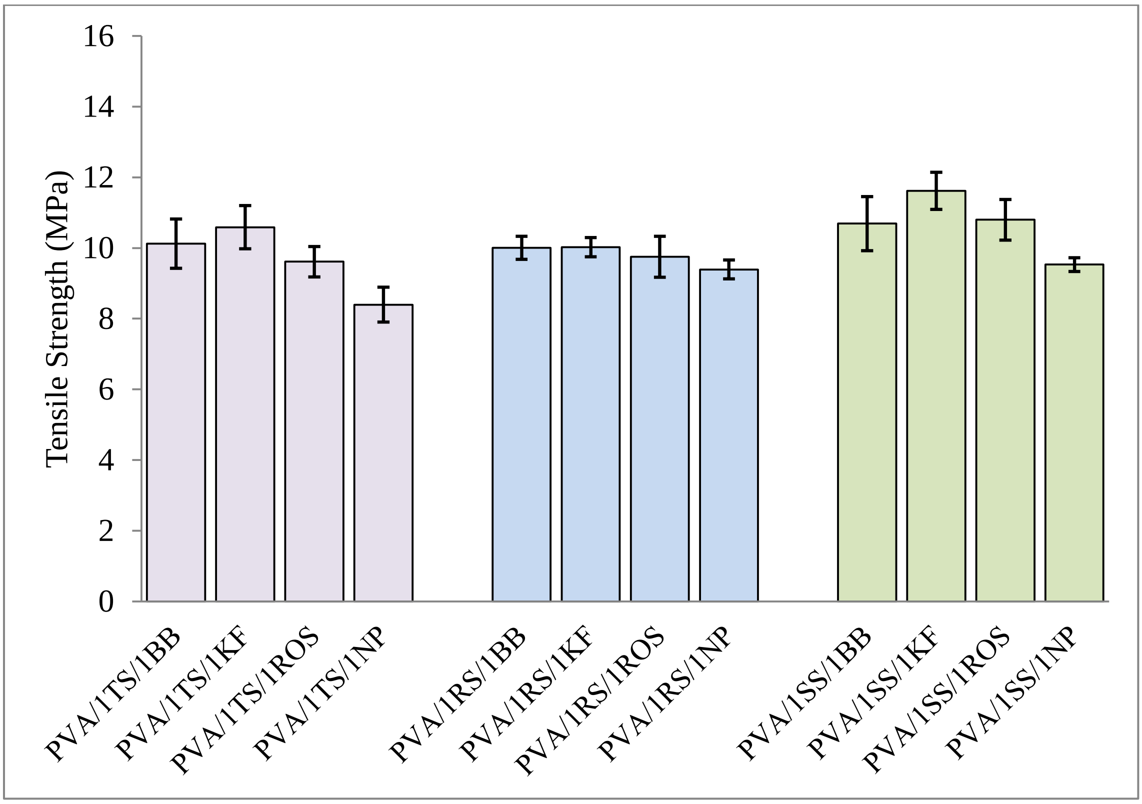

Fig. 4.182 Tensile strength values for different sets of PVA blended with 1g of different starches and reinforced with 1g of different fibers

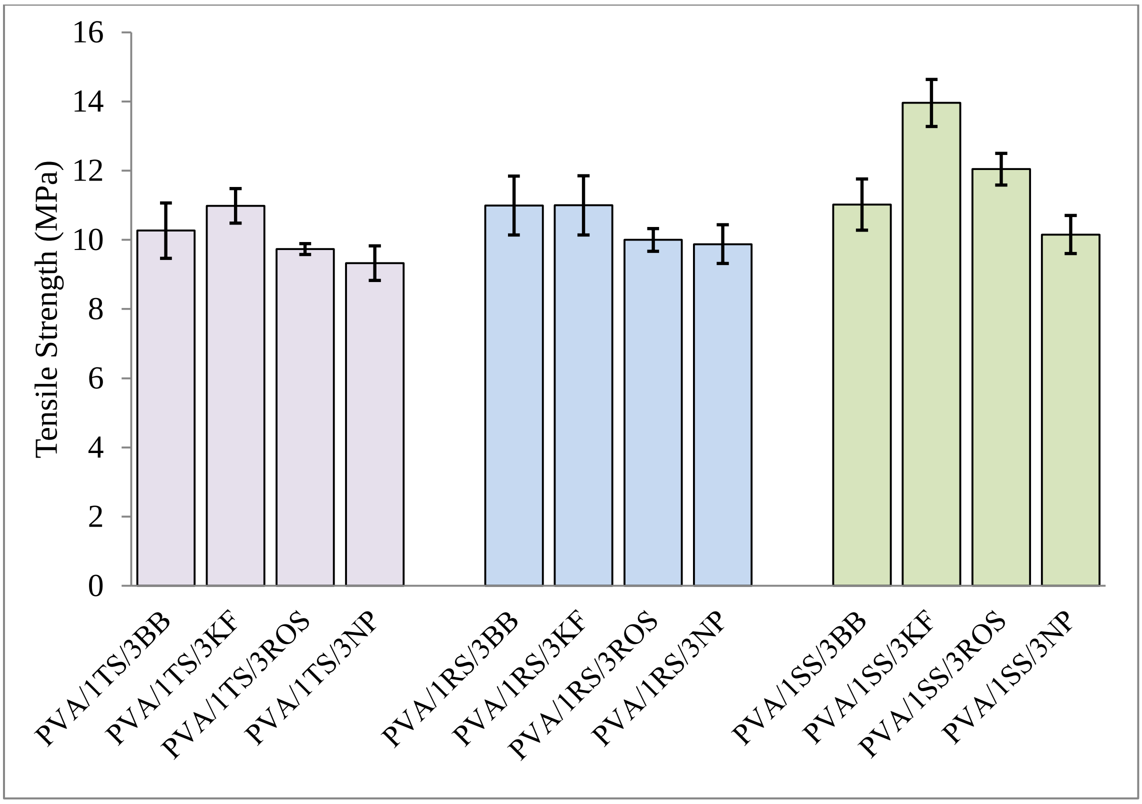

Fig. 4.183 Tensile strength values for different sets of PVA blended with 1g of different starches and reinforced with 3g of different fibers

From the SEM images of PVA blended with sago starch and different fibers in Section 4.1.3, it can be seen that the composite films showed homogeneous and random distribution of fibers in the form of bumps on the surface of the films. The fibers were well embedded and cemented in the continuous phase of the PVA/starch matrix and this will lead to strong interaction between the fibers and the PVA/starch matrix. This phenomenon may account for the slightly higher tensile strength value when compared to other composite blends. The slight increase in tensile strength of the PVA reinforced with treated fibers and blended with sago starch may also be contributed by the amylose content of sago starch. According to literature, composite films with high amylose starch have good tensile strength, tear resistance and impact strength compared to other starches with low amylose content (Lawton, 1996) (Follain, Joly, Dole, & Bliard, 2005) (Alves, Mali, Beleia, & Grossmann, 2007) (Yun & Yoon, 2009) (Zhao, Kloczkowski, & Mark, 1998). Comparison between the three starches used in this study, sago starch exhibits the highest amylose content as can be seen in Table 3.3 in Chapter 3.

When comparing the strength imparted by the different fibers used as reinforcement in the PVA/starch/fiber composites, it should be noted that composites reinforced with kenaf fibers showed the highest tensile strength values. Even though there is only a slight difference between the tensile strength values of the composites analyzed, both blends of PVA blended with different starches and reinforced with different concentrations of kenaf fibers shows high tensile strength values. According to literature, kenaf fibers have the highest cellulose content when compared to bamboo, roselle and napier fibers (Yan, Xu, & Yu, 2009). High content of cellulose leads to better stiffness and strength of the fibers when it is incorporated in the composites (Bhatnagar & Sain, 2005) (Bogoeva-Gaceva, et al., 2007). High cellulose content is a desirable property of a fiber when it is used as reinforcement in polymer composites.

For the composite of PVA blended with different starches and different concentrations of different fibers, the young modulus values are shown in Figure 4.184, 4.185 and 4.186, respectively.

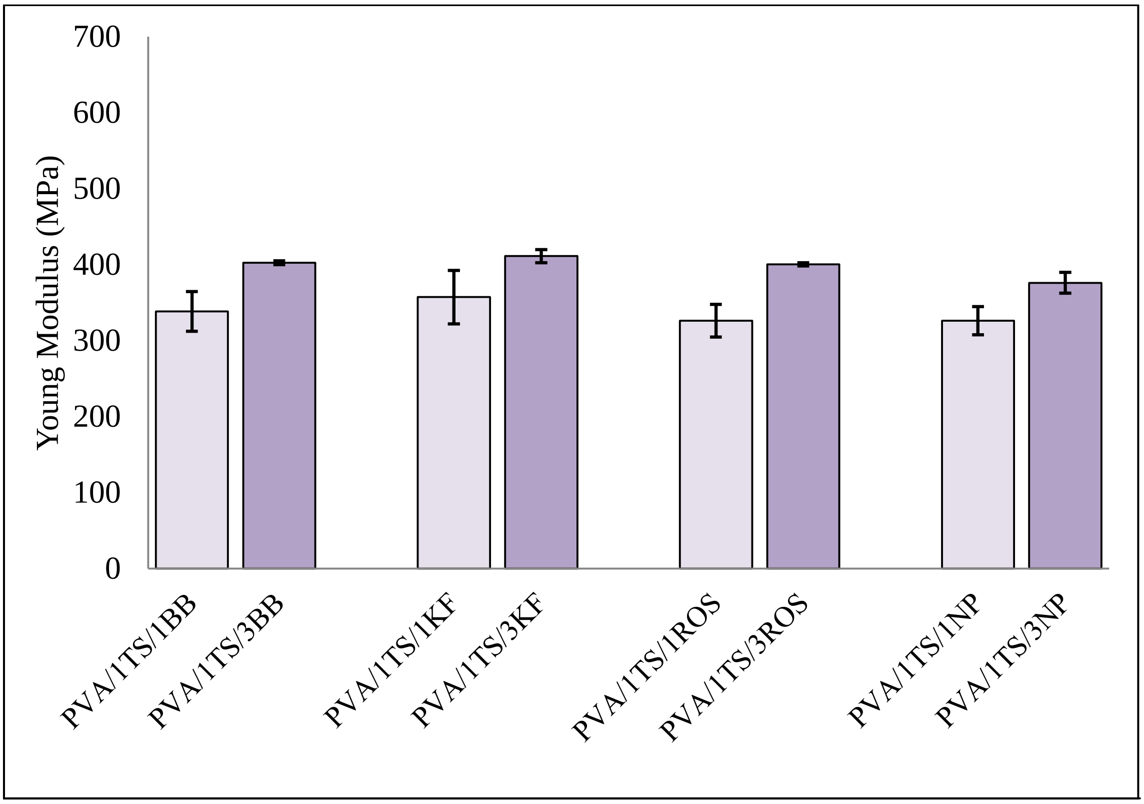

Fig. 4.184 Young modulus values for PVA blended with 1g of tapioca starch and different concentration of different fibers.

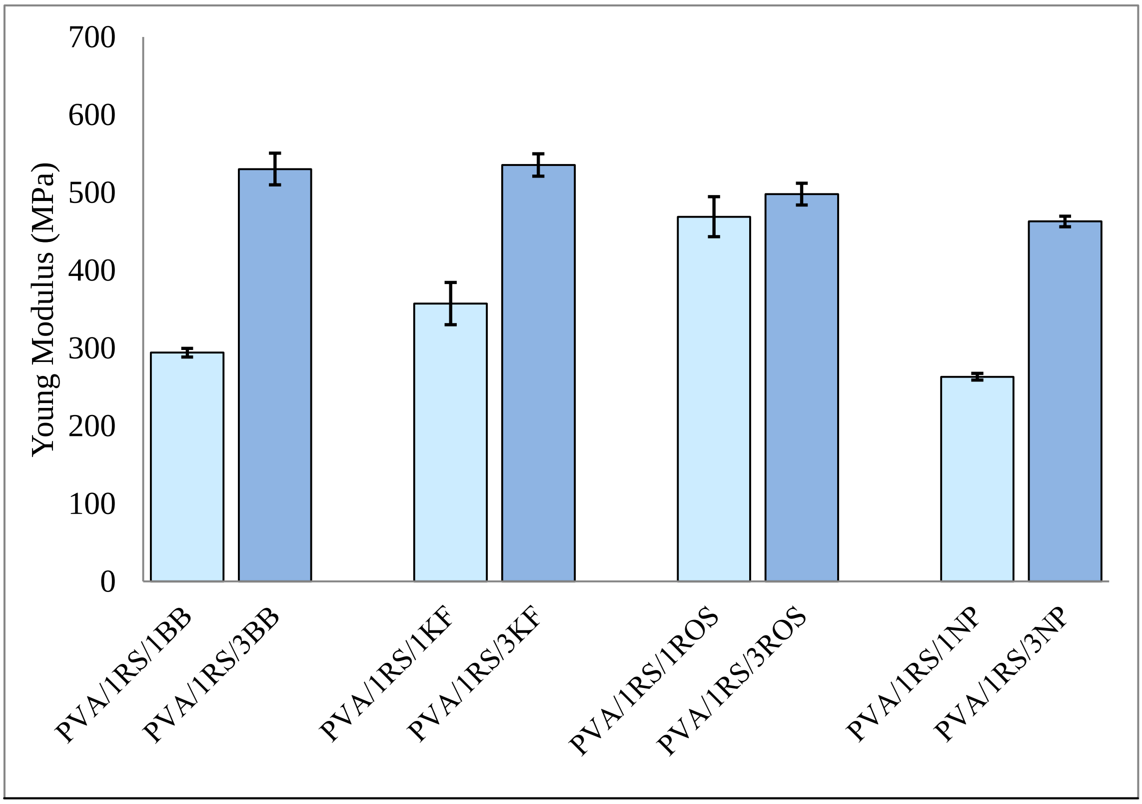

Fig. 4.185 Young modulus values for PVA blended with 1g of rice starch and different concentration of different fibers.

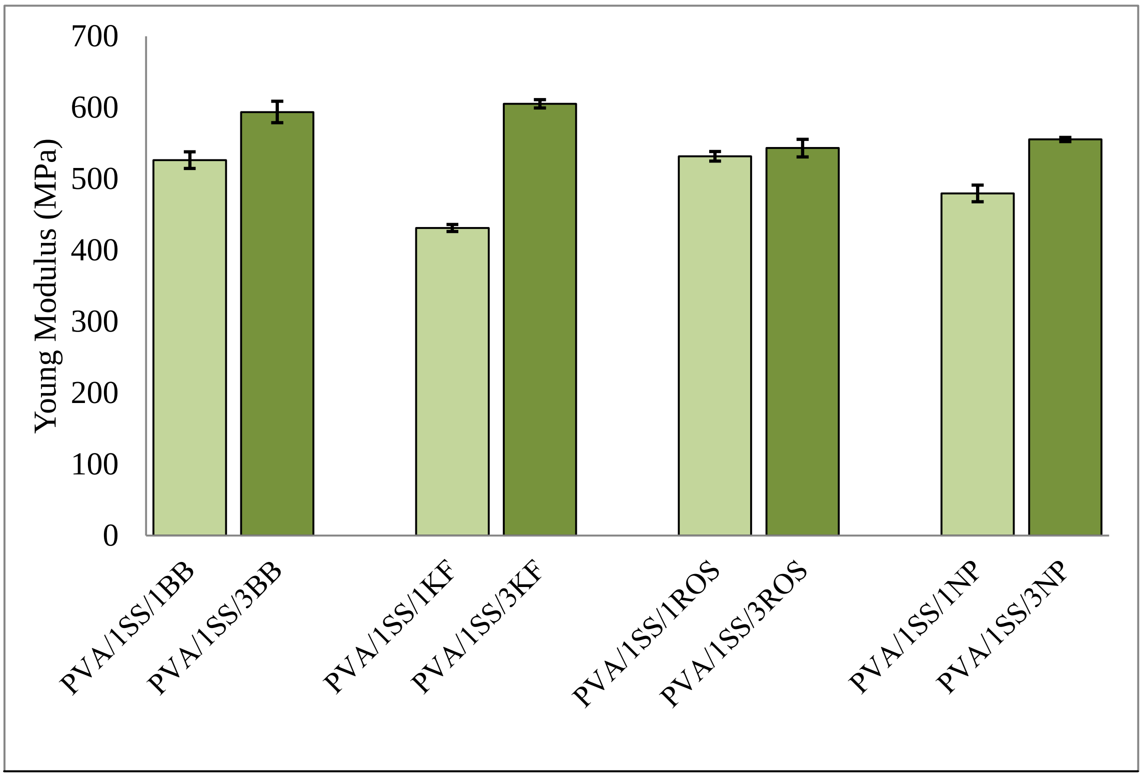

Fig. 4.186 Young modulus values for PVA blended with 1g of sago starch and different concentration of different fibers.

From the Figures 4.184 - 4.186, slight increments in the values of the Young modulus were observed with increasing concentration of reinforcement fibers in the composites. This behaviour suggests a strengthening effect of the fibers with a hardening in the composites. The increase in the composite stiffness as function of increasing concentration of reinforcement shows that the intrinsic mechanical properties of the reinforcement itself and the degree of dispersion of the filler into the polymer matrix are the key factors for increasing the rigidity of the composites. Even though the non-uniformity of the fibers used as reinforcement contributes to ineffective stress transfer between fiber and matrix, the intrinsic strength of the fiber itself imparts strength to the composites.

For the composite of PVA blended with different starches and different concentrations of different fibers, the percent elongation at break values are shown in Figure 4.187, 4.188 and 4.189, respectively.

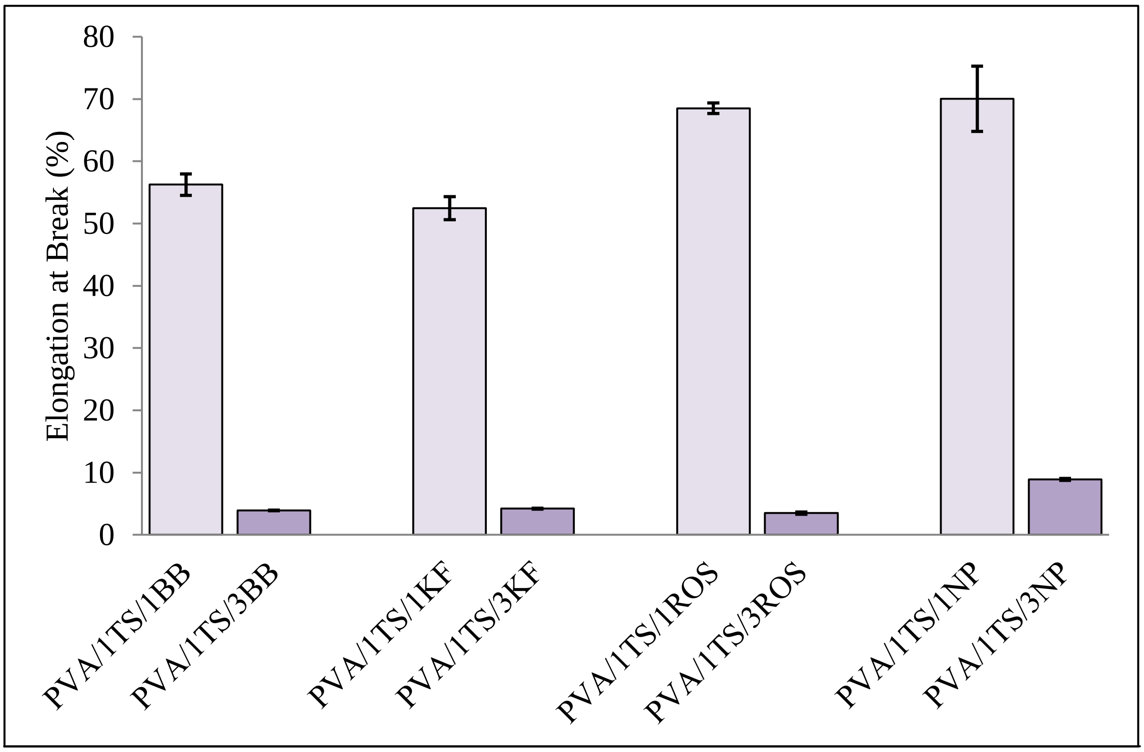

Fig. 4.187 Percent elongation at break values for PVA blended with 1g of tapioca starch and different concentration of different fibers.

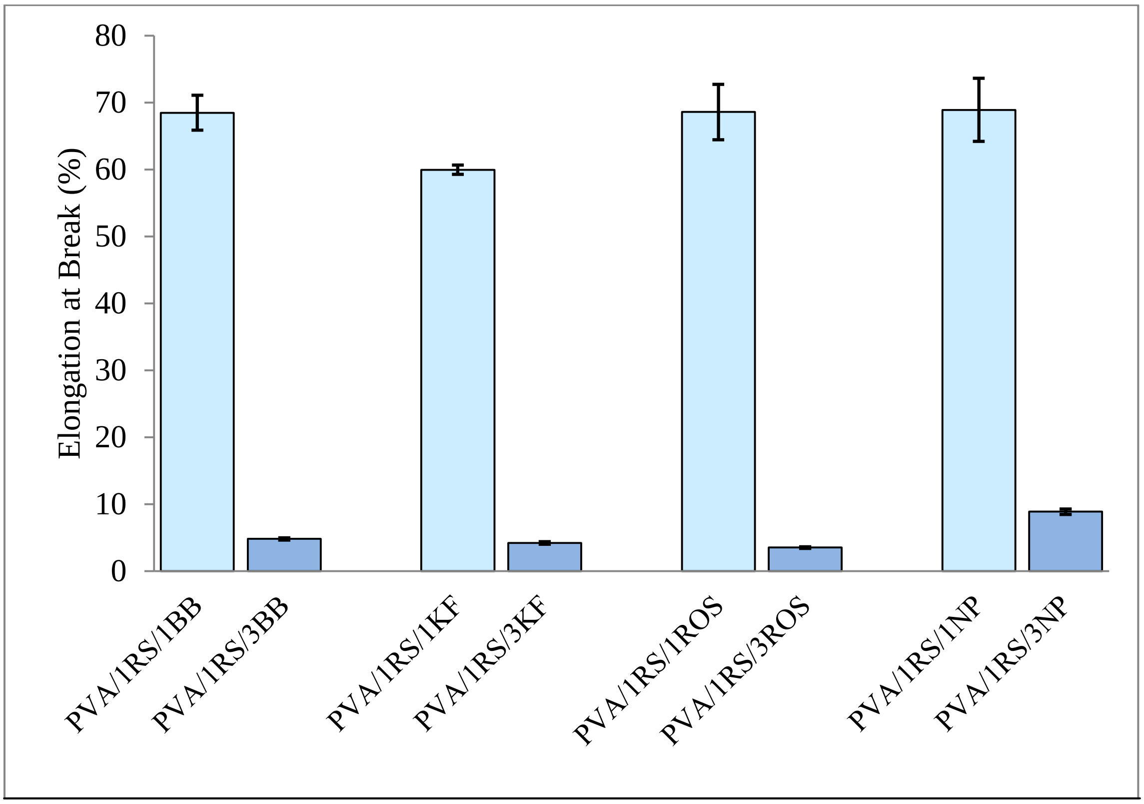

Fig. 4.188 Percent elongation at break values for PVA blended with 1g of rice starch and different concentration of different fibers.

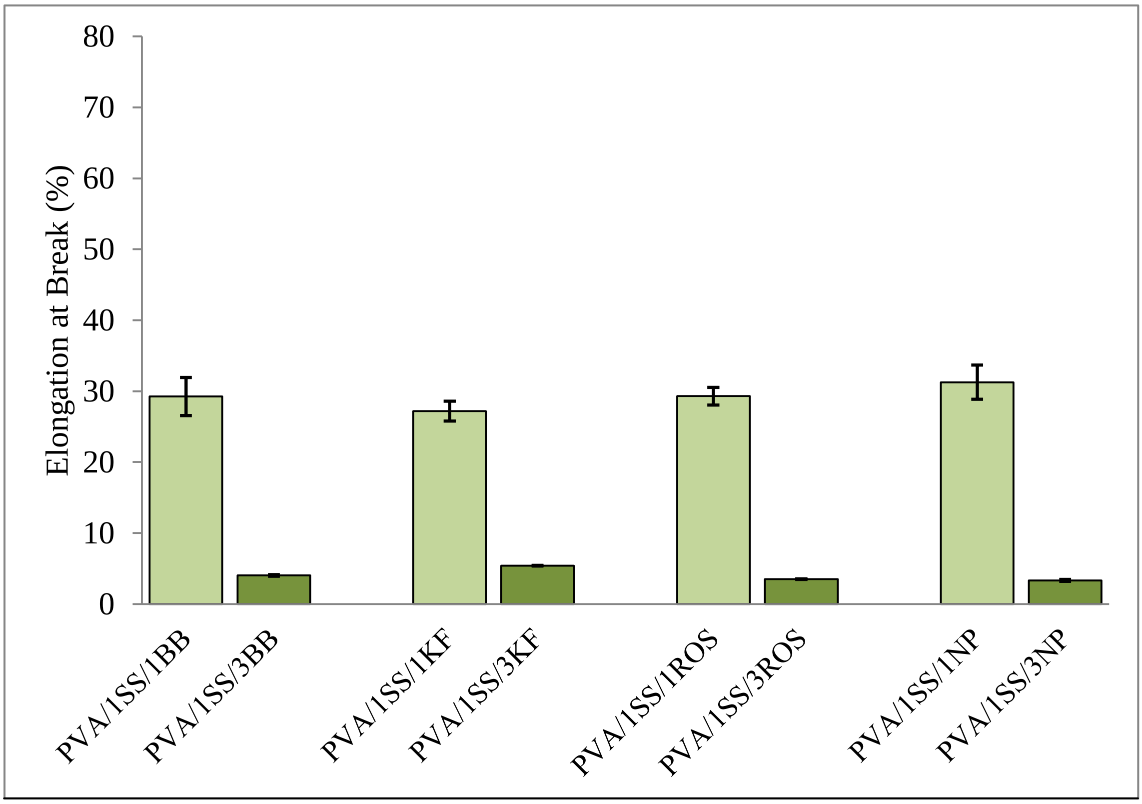

Fig. 4.189 Percent elongation at break values for PVA blended with 1g of sago starch and different concentration of different fibers

As can be seen from Figures 4.187 - 4.189, at low fiber content (1g), all of the composites were more flexible with higher percent of elongation at break than at higher fiber contents (3g). The percent elongation at break of the PVA/starch/fibers blends decreased considerably with the addition of higher concentration of fibers into the composites and this may be due to the rigid nature of the fibers reducing the ductile behaviour of the PVA/starch matrix phase.